Models to Inform Planning for the Future of Electric Power in the US: Some Fundamental Issues

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February 3, 2020

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Modeling Challenges: Two Guiding Thoughts

- "All models are wrong but some are useful," George Box, *Empirical Model-Building and Response Surfaces*, (1987, p. 424)
  - Models are an approximation to reality, not reality, so they always have some degree of approximation
  - Box went on to say that the practical question is how wrong to they have to be to not be useful
- “In theory, there is no difference between practice and theory. In practice, there is.” (often attributed to Yogi Berra, but substantially older)

Our Modeling Challenges

- We are ultimately trying to model one of the world's most complex machines
  - In North America our large-scale electric interconnects have billions of constantly changing components, and can be very nonlinear (e.g., when a transmission line opens)
- The grid is rapidly changing, especially with the integration of large amounts of renewable energy
- When good models are needed the most, such as during times of "In Extremis" operation (to quote Fink and Carlsen, *IEEE Spectrum,* 1978), they are often at their worst

A Challenge: Addressing Some Fundamental Issues

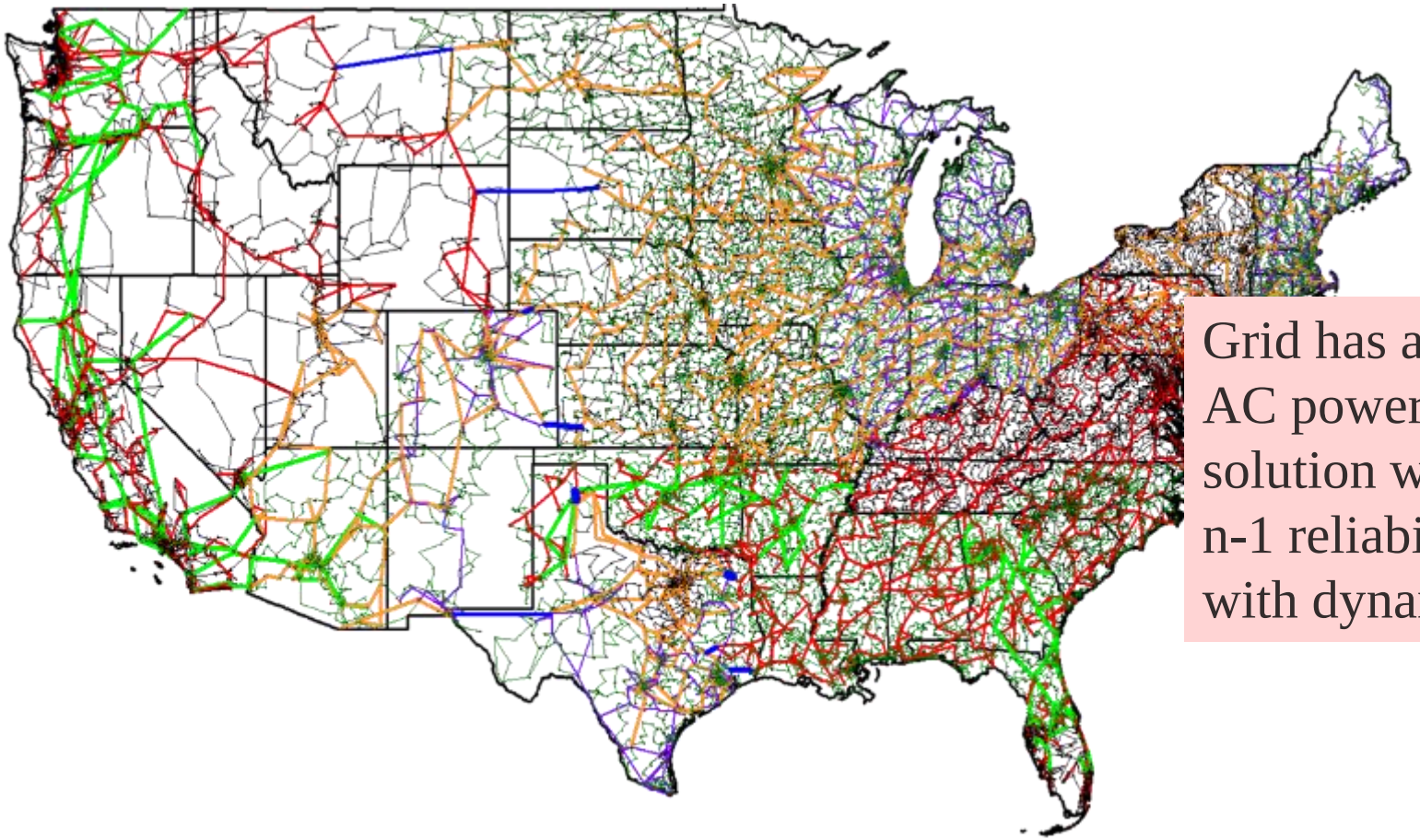
- To address these issues we need to effectively leverage the broad community of researchers and practitioners
- Too often the academic research community has been focused on solving the wrong problems
  - Utilizing small-scale and/or simplistic electric grids that fit well with graduate level research
  - Real grids can be quite complex and nonlinear!
- When large, realistic grid models are used they cannot be shared because of legitimate Critical Energy/Electricity Infrastructure Information (CEII) concerns

A Recent Success: Synthetic Electric Grids and Datasets

- Synthetic electric grids are fictional representations that are free from confidential information and hence can be freely shared
- Two recent National Academies Reports (2016 and 2017) called for greater research in this area
- Over the last four years tremendous progress has been made through various U.S. ARPA-E projects in the creation of large-scale, high quality, realistic synthetic grids at both the transmission and distribution levels
- Goal is that innovation done with these grids can be directly applied to the actual grid

Current Status: Large-Scale Grids are Now Available

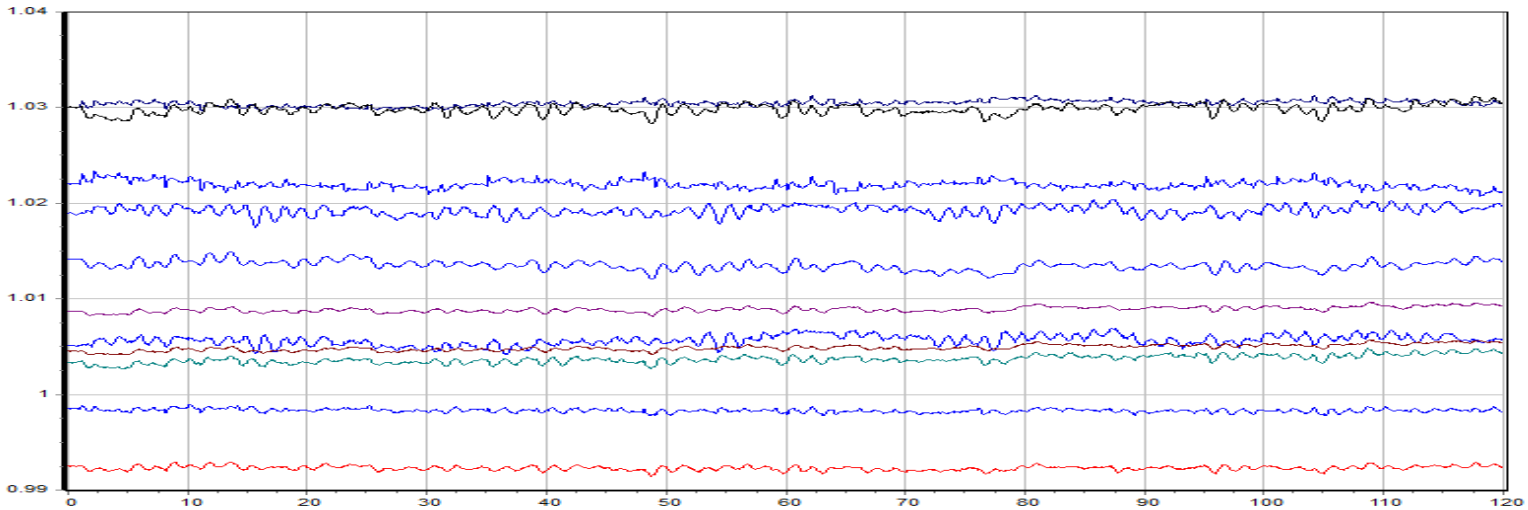
This is an 82,000 bus synthetic model that was publicly released in summer 2018 at **electricgrids.engr.tamu.edu**



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

Synthetic PMU Data

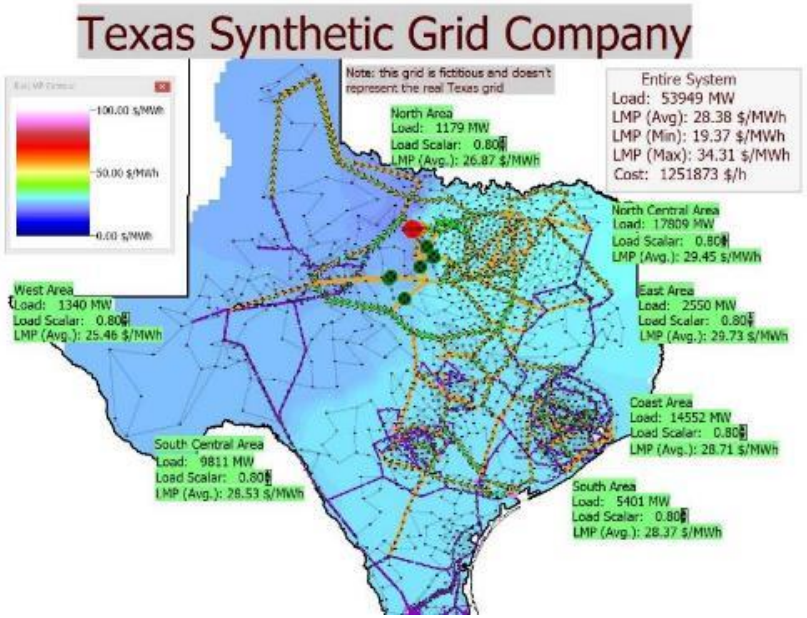
- Large amounts of synthetic, public PMU data is now being created based on such dynamic simulations with realistic variation in the load and generation and the appropriate types of errors
  - Validation is crucial, but is aided by public access to this data and the associated models allowing for informed critique



Utilizing Large-Scale Grids in Education

- At Texas A&M we are utilizing large-scale systems in undergraduate and graduate courses, and giving students experience operating simulated grids

2000 Bus Undergraduate Lab OPF Example

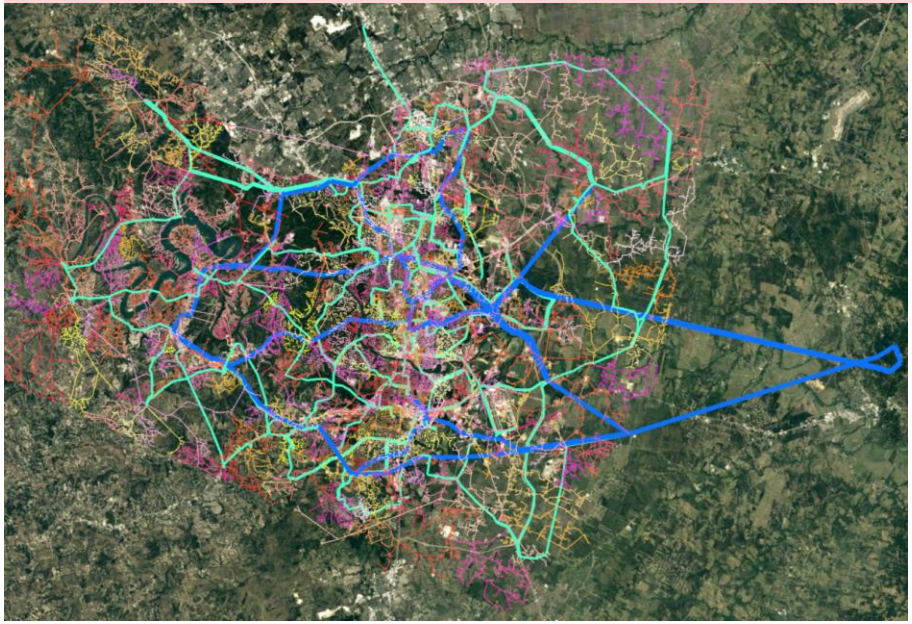


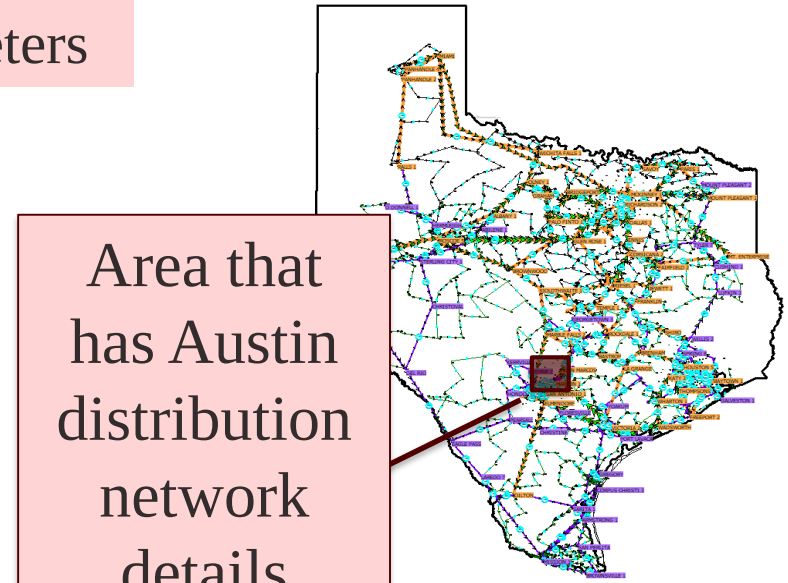
Texas A&M Control Center Lab

Combined T&D Electric Grid Models are Becoming Available

- A current U.S. ARPA-E is focused on the creation of large-scale, time-vary electric grids that go from the transmission down to the meter
  - Soon we'll have a grid for Texas with 10 million meters

Austin 230/69 kV Grid with 300K meters





Area that has Austin distribution network details

A Need: Support for Publications Focused on Practitioner Needs

- Academic research is often driven by money and publications (H index, journal impact factor, etc.)
- Too often the easiest papers to publish are ones that reduce the system complexity to allow for rigorous mathematical modeling
  - Simple and elegant; well reviewed because the papers align with the academic interests of reviewers and editors
- The hardest to publish are the ones that address the complexities of actual systems; that is, the needs of practitioners
- A finding and recommendation in this area could be a quite important study contribution