Transient stability modeling using highly detailed synthetic electric grids with distribution system applications

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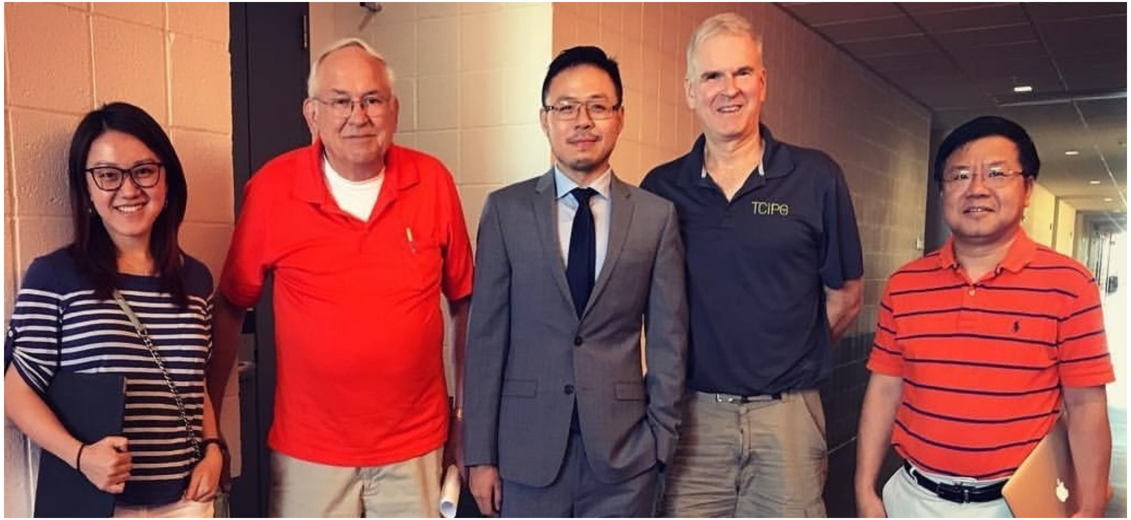
Ti Xu, 1988-2018

- Some of the work presented here was done by my former graduate student and postdoc Ti Xu



Introduction

- Our modern society depends on reliable electricity; large blackouts can be catastrophic
- Interconnected electric grids world-wide are in a period of rapid transition, with much of it at the distribution level and/or impacting grid dynamics
  - Changing load and generation, customers with choice in their electric service, inclusion of new technologies
- There are lots of opportunities for innovation!

Data and Model Access Barriers

- In many places worldwide access to data about the actual power grid is restricted because of needs for confidentiality (e.g., in US CEII)
  - Data and models are sometimes available through NDAs, but ability to publish and distributed is limited
- To do effective research researchers need access to common, realistic grid models and data sets

Solution: Synthetic Electric Grids

- Synthetic electric grids are fictional representations that are free from confidential information
- Over the last three years tremendous progress has been made through the U.S. ARPA-E in creating large-scale, high quality, synthetic grids at both the transmission and distribution levels

Solution: Synthetic Electric Grids

- Validation with actual electric grids and data sets has been a crucial component of this research
- Goal is that innovation done with these grids can be directly applied to the actual grid
- Talk focuses on recent work on combined transmission and distribution system models with dynamics

Electric Grid Time Frames

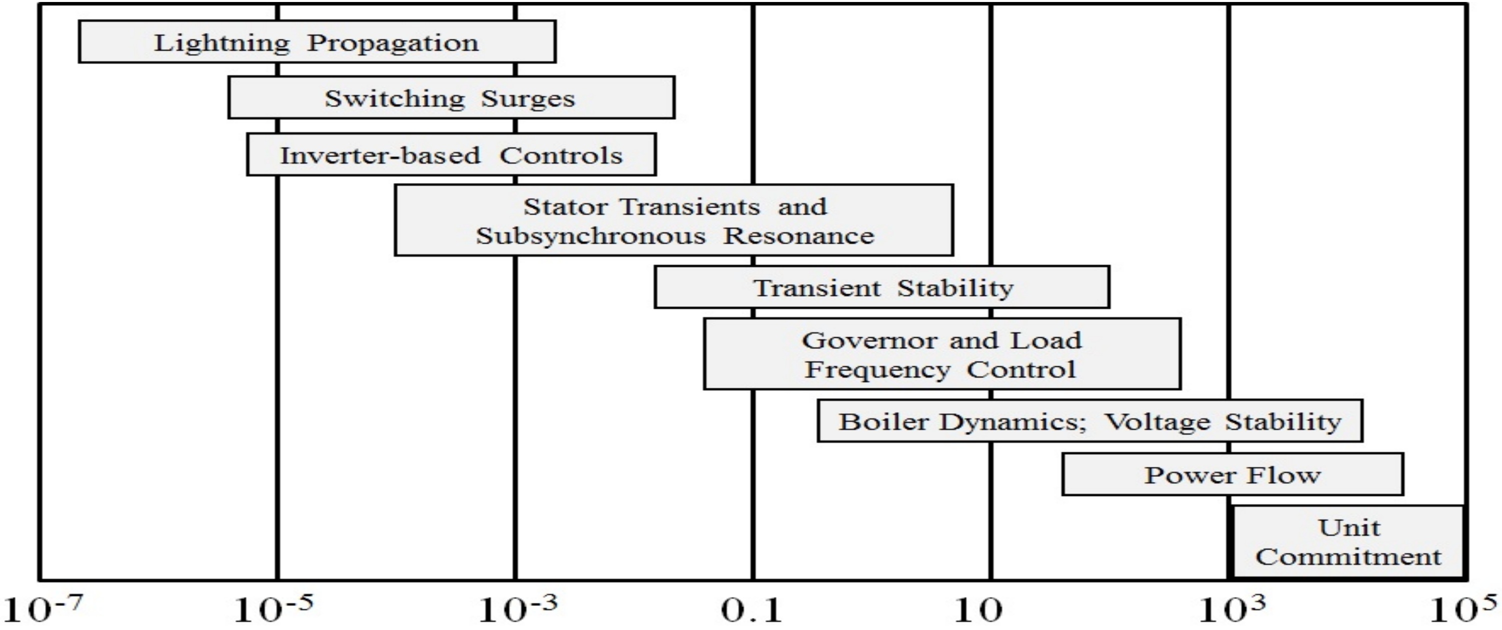
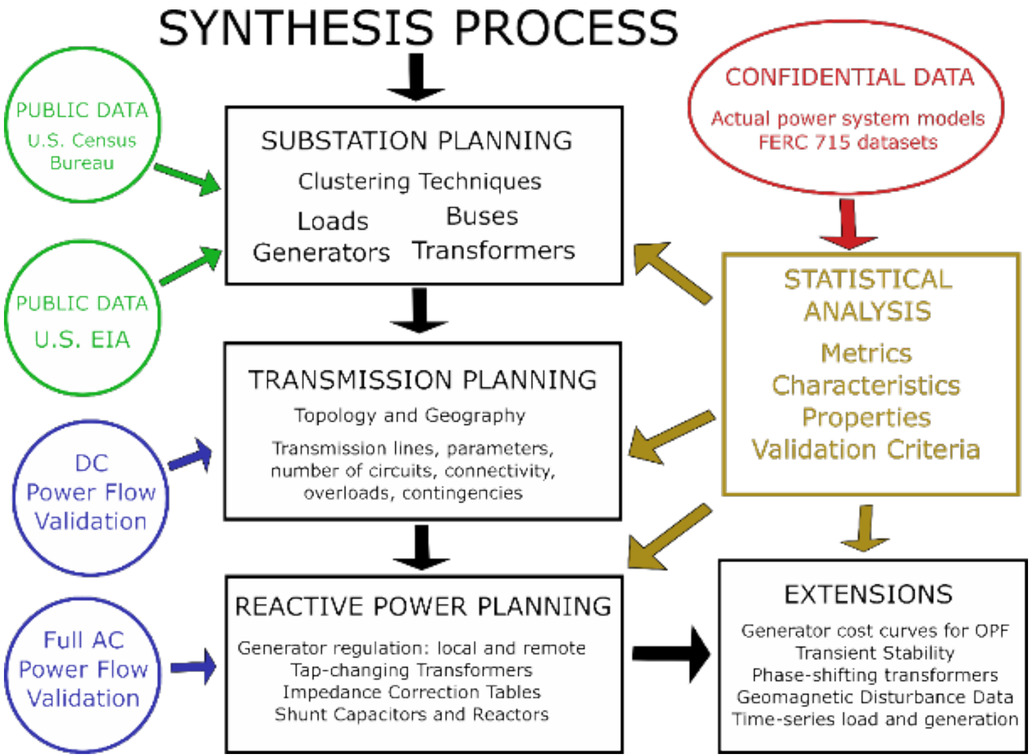


Image source: P.W. Sauer, M.A. Pai, Power System Dynamics and Stability, 1997, Fig 1.2, modified

Our Synthetic Grid Approach

- Make grids that look real and familiar by siting them geographically (North America for us) and serving a population density the mimics actual
- Goal is to leverage widely available public data
  - Geography and population density now down to the parcel
  - Load by utility (US FERC 714), state-wide averages
  - Existing and planned generation (Form US EIA-860, which contains lots of generator information)

Synthetic Model Design Process

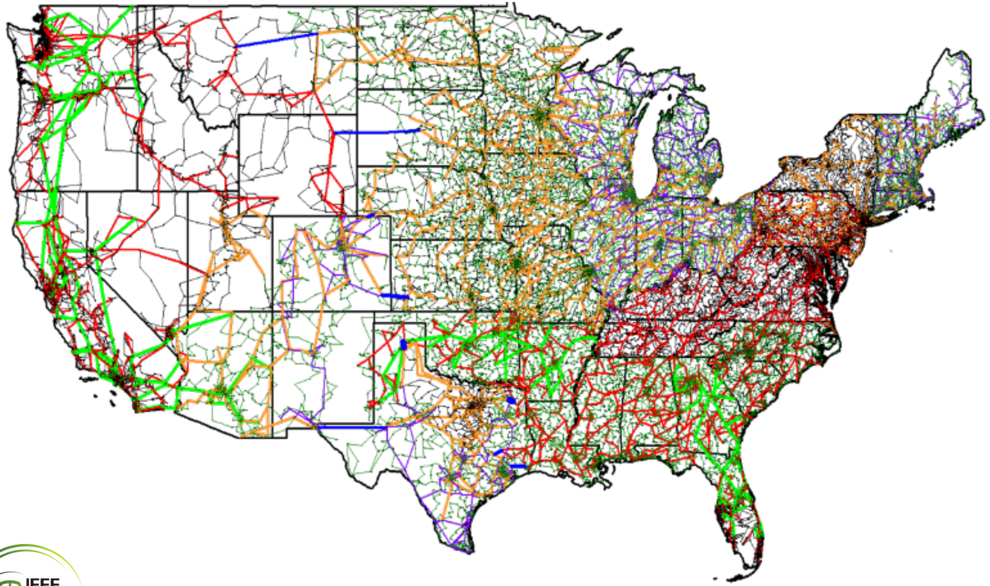


The assumed peak load is based on population, scaled by geographic values

Much of this is automated, but there is still some manual adjustment

Current Status: Transmission

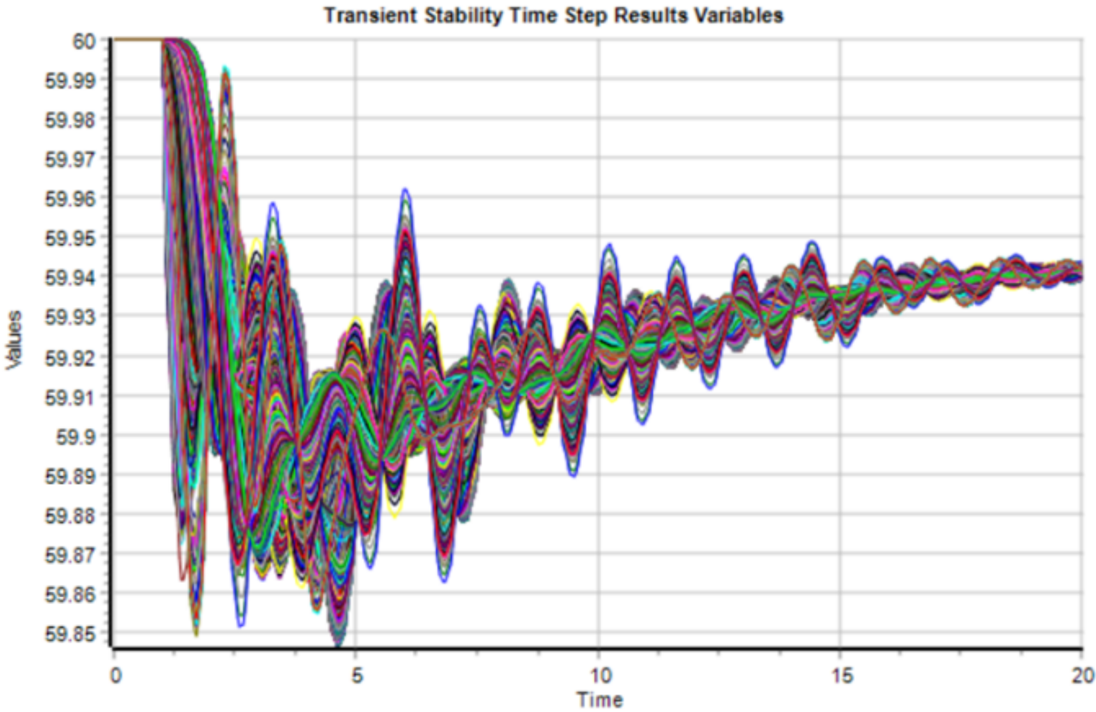
This is an 82,000 bus synthetic model that we publicly released in summer 2018 at **electricgrids.engr.tamu.edu**



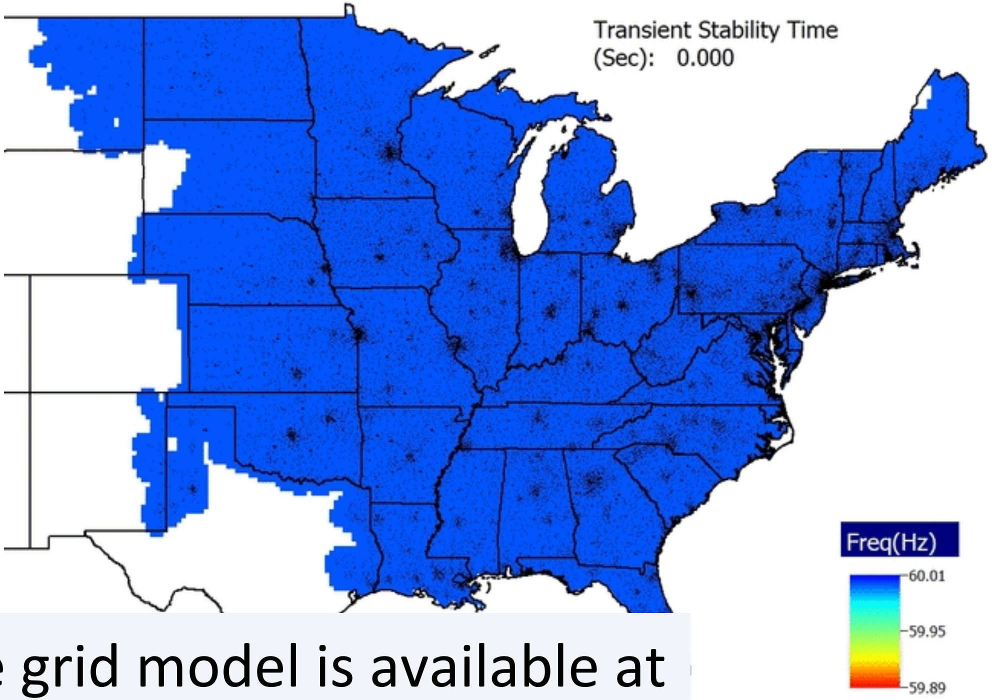
Substation locations and the transmission system is entirely fictional ("realistic but not real"). Grid has an ac power flow solution with n-1 reliability

These Grids Also have Dynamic Models

- This slides shows the frequency response of our US Western grid to a double generator outage; at first glance it looks like the WECC



Grid Dynamics



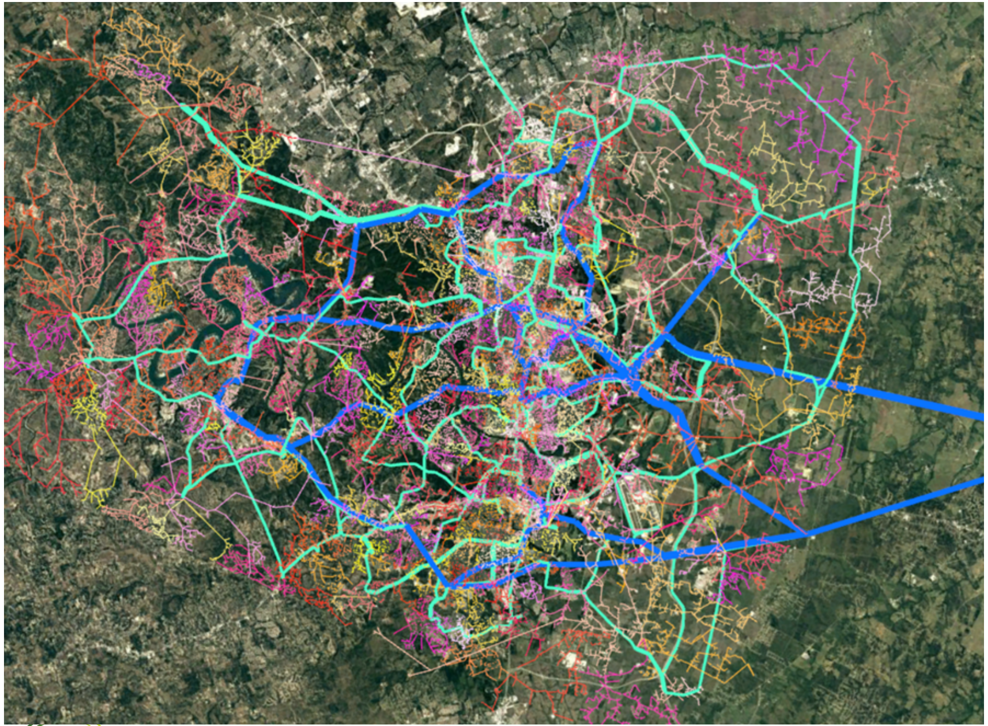
These results were created using a 70K bus system with detailed dynamic models for 8000 generators. The models and all the data associated with this image are public

The grid model is available at
electricgrids.engr.tamu.edu

Moving Down to the Individual Meters

- Our initial work stopped at the 69 kV level, and was geographically realistic to the zip code level
- Our new work, partnering with NREL, is to combine transmission models with distribution system models that supply electric meters located at actual parcels
- The resultant distribution systems tend to be quite geographically realistic

Example: Travis County, TX



This is a synthetic grid, but utilizing a quite realistic layout; blue is 230 kV, light green 69 kV, and lots of distribution lines down to hundreds of thousands of electric meters.
This fall we will be doing all of Texas with about 10 million meters.

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Distribution Level Dynamics

- The primary distribution level transient stability time frame dynamics come from the load and the distributed energy resources (DERs)
  - New models have been introduce to represent various distribution driven dynamics
  - The composition and hence the dynamics of the load and DERs can be highly time-varying

Combined Transmission and Distribution

- With complete models we can study want parts the system need to be modeled and at what detail. For example
  - Transmission only
  - Distribution only
  - Full electrical models for transmission and distribution
  - Full transmission with detailed distribution topology only but including attributes like whether a parcel has pv

Developing Time-Varying Dynamics

- Our approach to developing time-varying dynamics models in the distribution system is to assign attributes to the individual electric meters and then develop the dynamic models bottom-up.
  - For example, some meters have PV; how much is on depends on solar irradiance at the location; some have air conditioning with amount dependent on ambient conditions; some have electric vehicles, etc.

Where We Are Going

- We are developing a set of time-varying scenarios in which potential grids of the future can be tested under a wide-variety of different conditions
  - They will be driven by transient stability level dynamic models including distribution level dynamics
- The environment will also allow teams to operate an electric grid under a wide variety of conditions

Texas A&M Control Room Laboratory

- The simulation will also allow for the testing of different power system visualizations

Thank You!

Questions?