Power System Long-Term Dynamic Simulation using Time-Sequenced Power Flows

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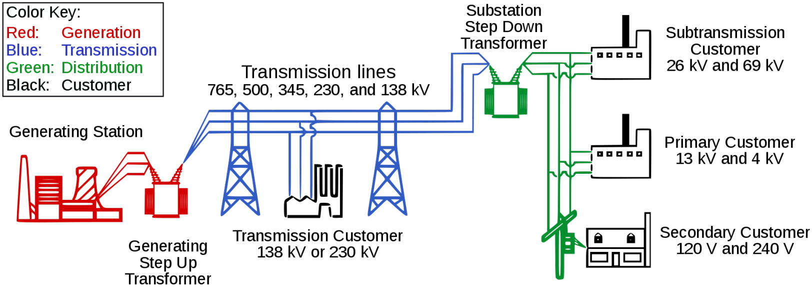
Montana Technological University - Master's Thesis Research Project

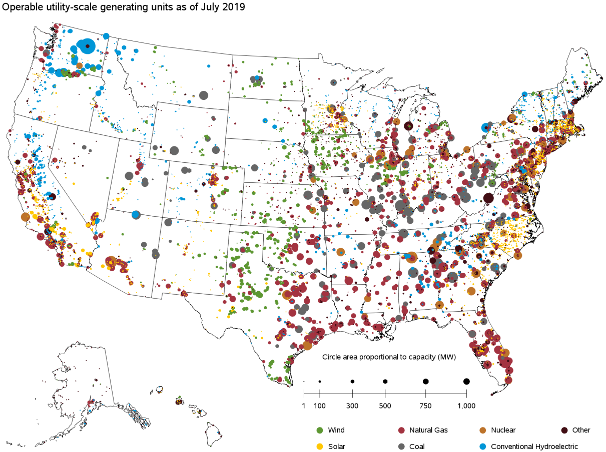
October 22nd, 2019

What is a Power System?

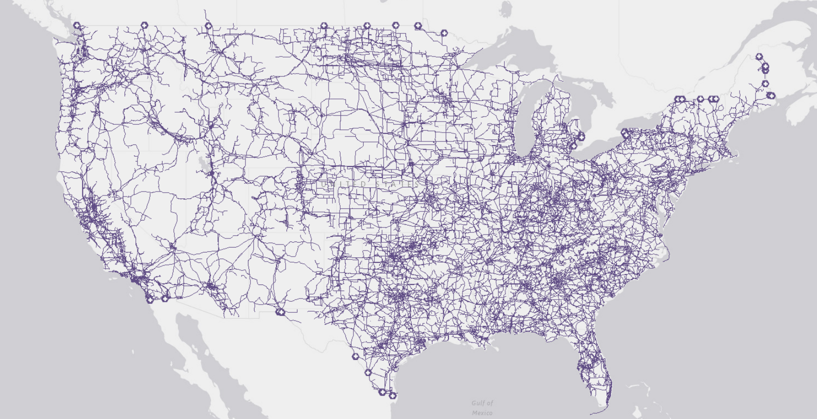


Electrical supply connected to demand.

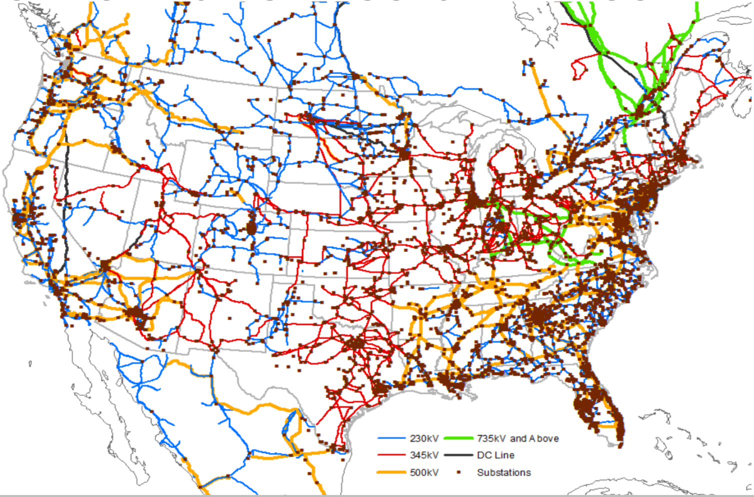
U.S. Electric Generation



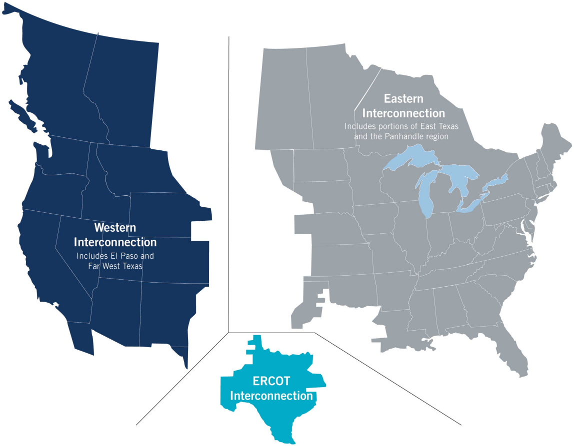
U.S. Electric Transmission Lines



Electric Transmission Lines

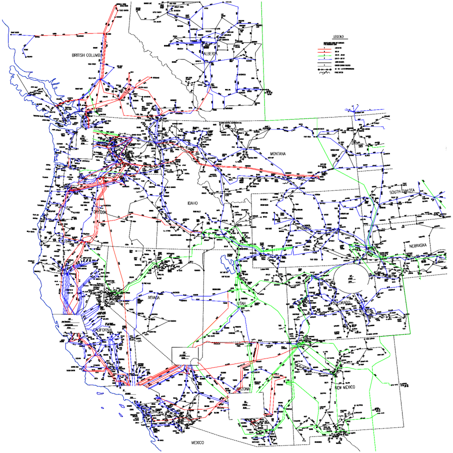


Interconnections



WECC Model

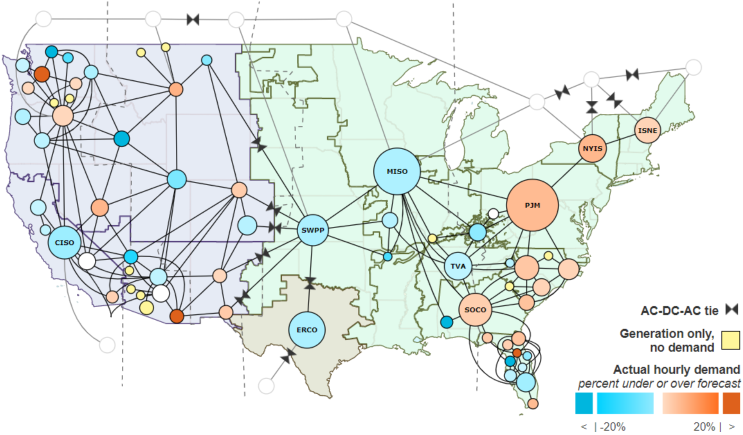
- 21,879 Buses
- 17,210 lines
- 4,231 Gens
- 11,048 Loads



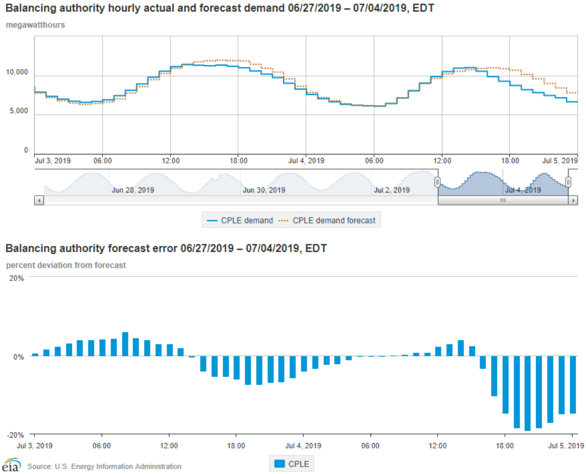
'People in Charge'

- **FERC** Federal Energy Regulatory Commission
  Part of the Department of Energy
- **NERC** North American Electric Reliability Corp.
  Aurthority granted by FERC
- **Balancing Authority** (BA)
  Manage specific portions of the power system to balance supply and demand and maintain mandatory operating conditions set by FERC and NERC.

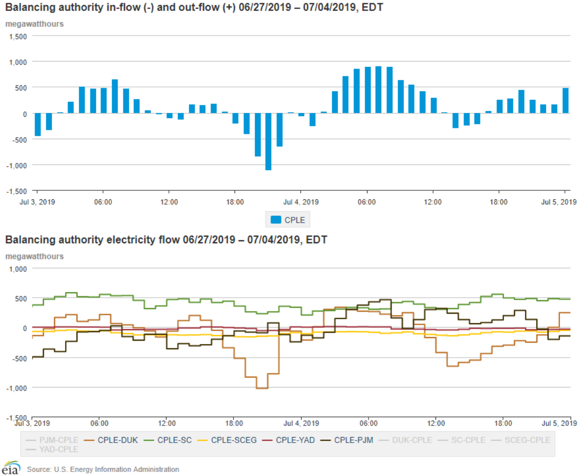
Balancing Authorities (BAs)



BA Action - Forcasting

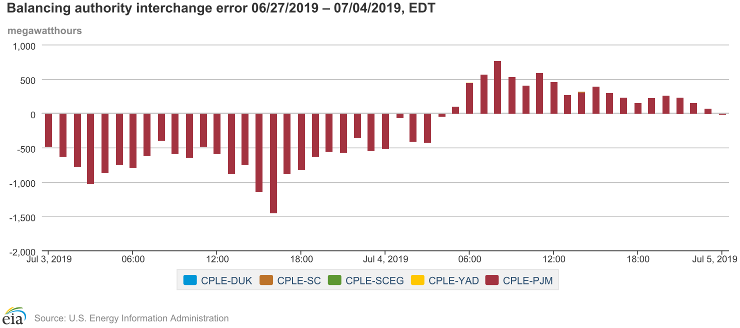


BA Action - Interchange



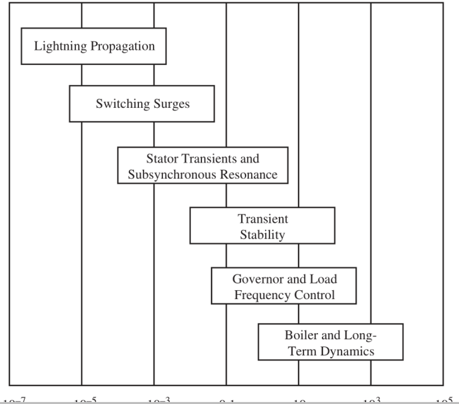
BA Action - Interchange Error

≈ Area Control Error



What is Long-Term?

- 1 sec $\leftrightarrow$ hours
  $\therefore$
- 10$\rightarrow$60 minute simulations
- 1 sec time step



What is Dynamic Simulation?

A computer's mathematical solution to how a system may change over time.

Think solving ODE's.

How certain qualities of a power system may change over time in response to a known perturbance.

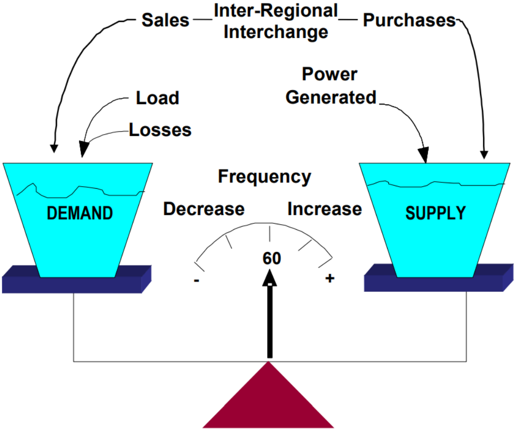
Frequency (ω)

$$\dot{\omega}_{sys} = \frac{P_{acc,sys}}{2H_{sys}\omega_{sys}(t)}$$

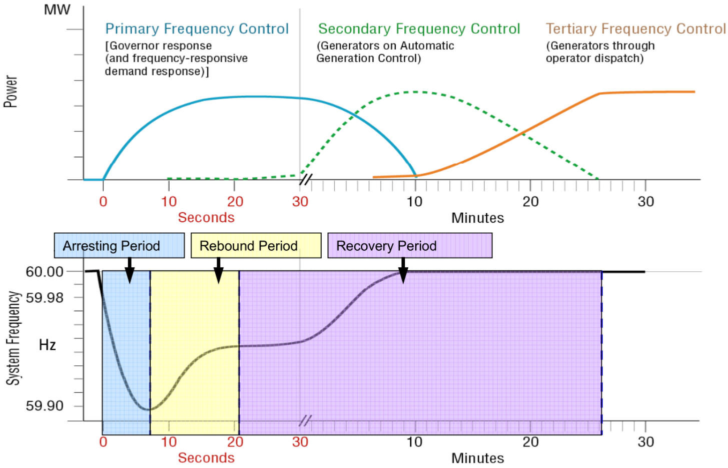
$$P_{acc} = P_{gen} - P_{load}$$

Electric demand always met.

Demand always changing.

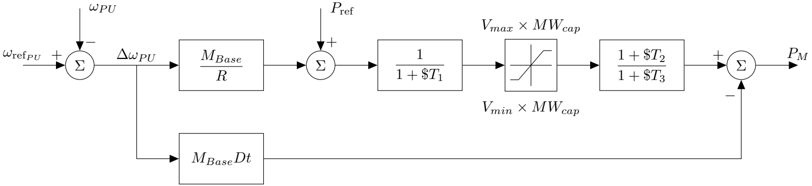


Automatic Controls



Turbine Speed Governors

Primary control.
Governors adjust turbine mechanical power to arrest frequency decline.

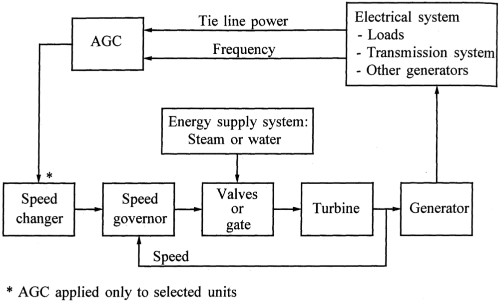


Dynamic Variable: Fuel Valve Position

Automatic Generation Control

Secondary Control.

Correct frequency and interchange error.



Kundur

Dynamic Variable: Area Control Error

What is a Power Flow?

A steady state solution to all bus voltages, bus voltage angles, and real and reactive power of a system.

A *snapshot* of a stable power system.

Power flows are not dynamic.

Time-Sequenced Power Flows?

Multiple power flows arranged in a way to give the allusion of time.

A *flip book* of *snapshots*.

Allows for additional dynamics to be calculated between *snaps*.
(i.e frequency, valve position, etc.)

Why use this method?

Allows for:

- Simplifications
- Greater access to data
- Customizable models
- Modern programming language
- Further future work

So, what's happening?

Essentially:

- Executing computer simulations of the western interconnection that are over 10 minutes long.
- Simulation 'time steps' are a sequence of power flows (*snapshots*)
- Additional dynamic calculations are performed between each 'time step'.

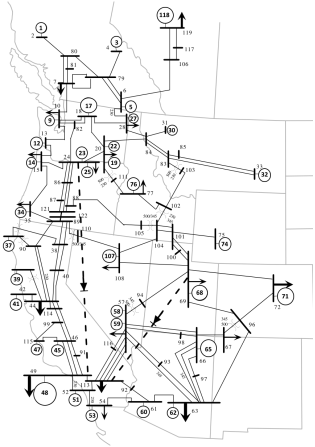
And why?

To study engineering problems involving:

- Long-term events (i.e. Wind Ramps)
- Multi-Area Power Interactions
  - Governor and AGC interaction
  - Governor and AGC settings
- Ways to reduce machine effort while meeting reliability standards.

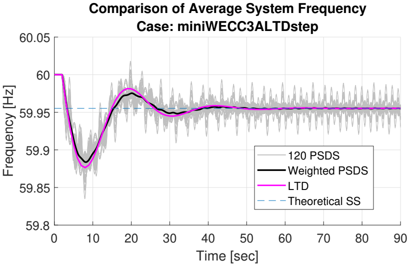
miniWECC Model

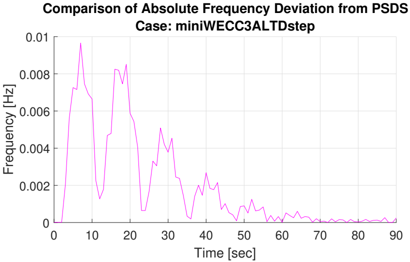
- 120 Buses
- 104 lines
- 34 Gens
- 23 Loads



Step Perturbance Validation

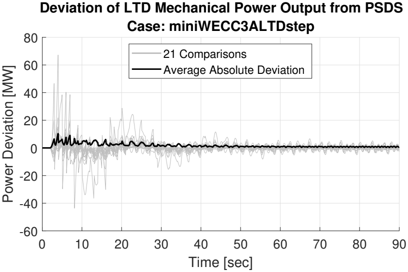
400 MW Load Step Frequency Comparison

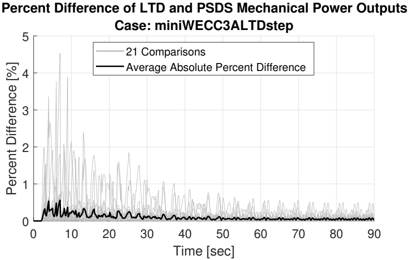




Step Perturbance Validation

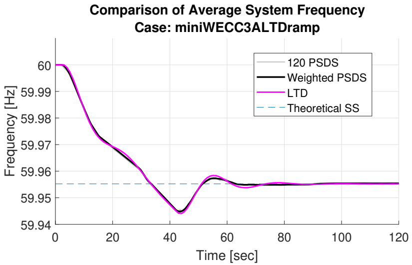
400 MW Load Step Mechanical Power Comparison

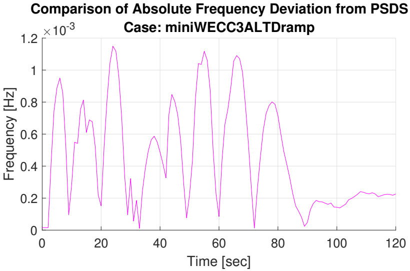




Ramp Perturbance Validation

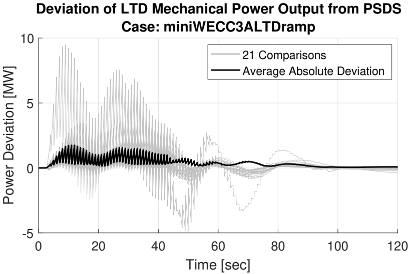
20 second 400 MW Load Ramp Frequency Comparison

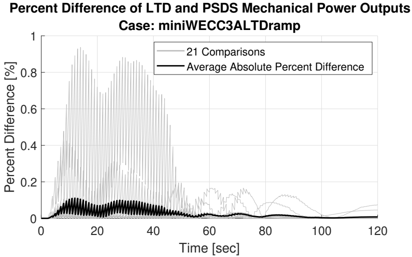




Ramp Perturbance Validation

20 second 400 MW Load ramp Mechanical Power Comparison





Governor Deadband Options

Pic of deadband options

Governor Deadband Results

BA gov deadband action - do a step deadband, and ramp deadband f comparison
should see ’knocking’ with step, assumed to be resolved with ramp...

Current Conclusions

- Software (PSLTDSim) output appears valid for tested systems.
- Governor and AGC interactions can happen easily.
- Advanced control can be used to limit governor and AGC conflicts as well as reduce overall machine effort.

Continuing Work

- Experiments with AGC and turbine speed governor settings.
- Use of valve travel and system reliability to gauge validity of control regime.
- Expansion of software capabilities to handle full WECC.

Questions?

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