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

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Montana Technological University - Master's Thesis Research Project

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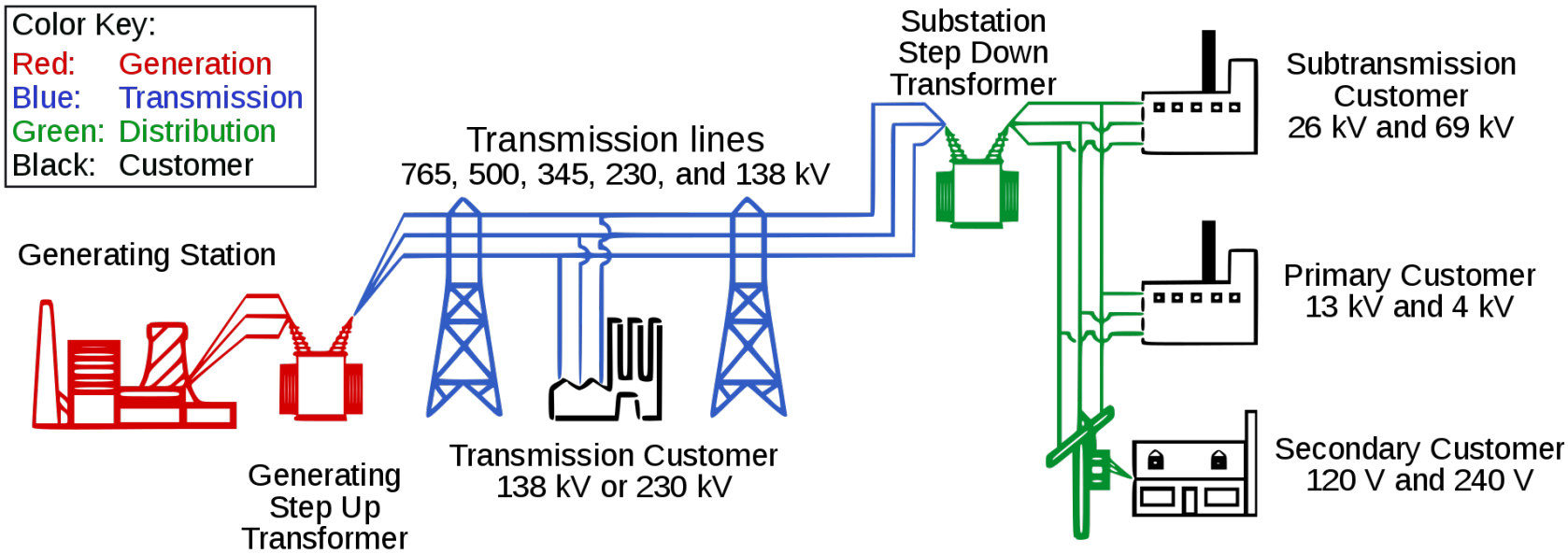
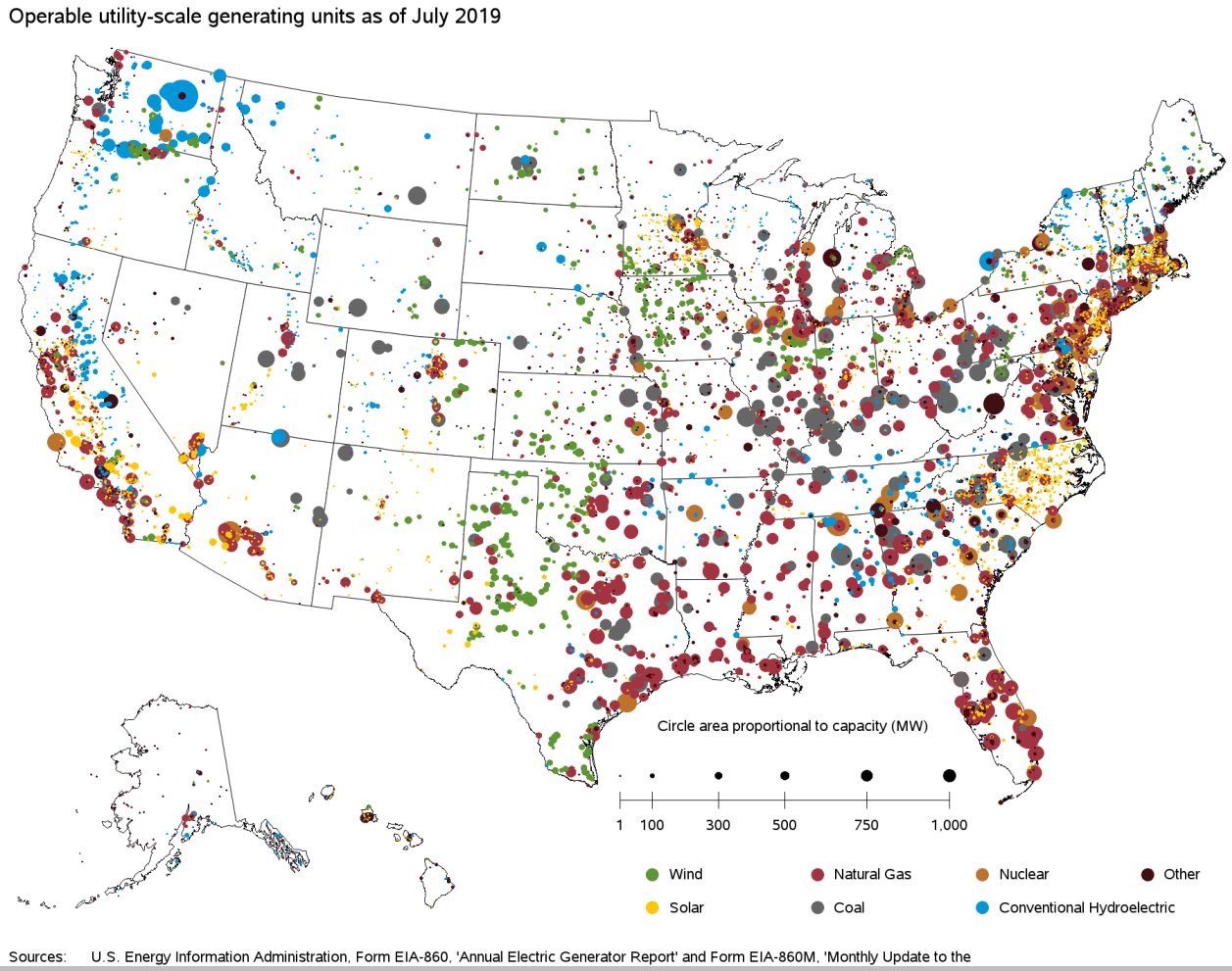
What is a Power System?

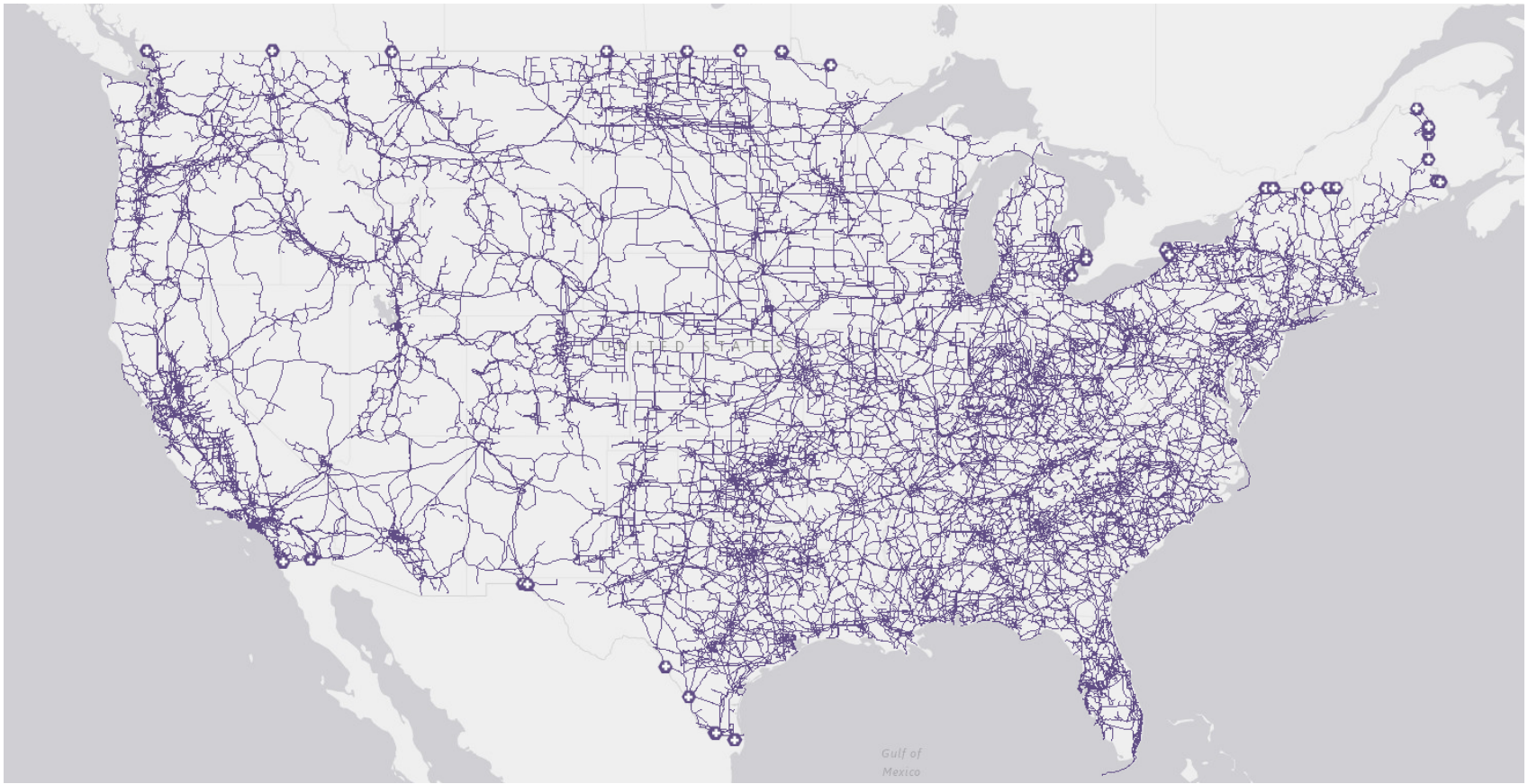


Electrical supply connected to demand.

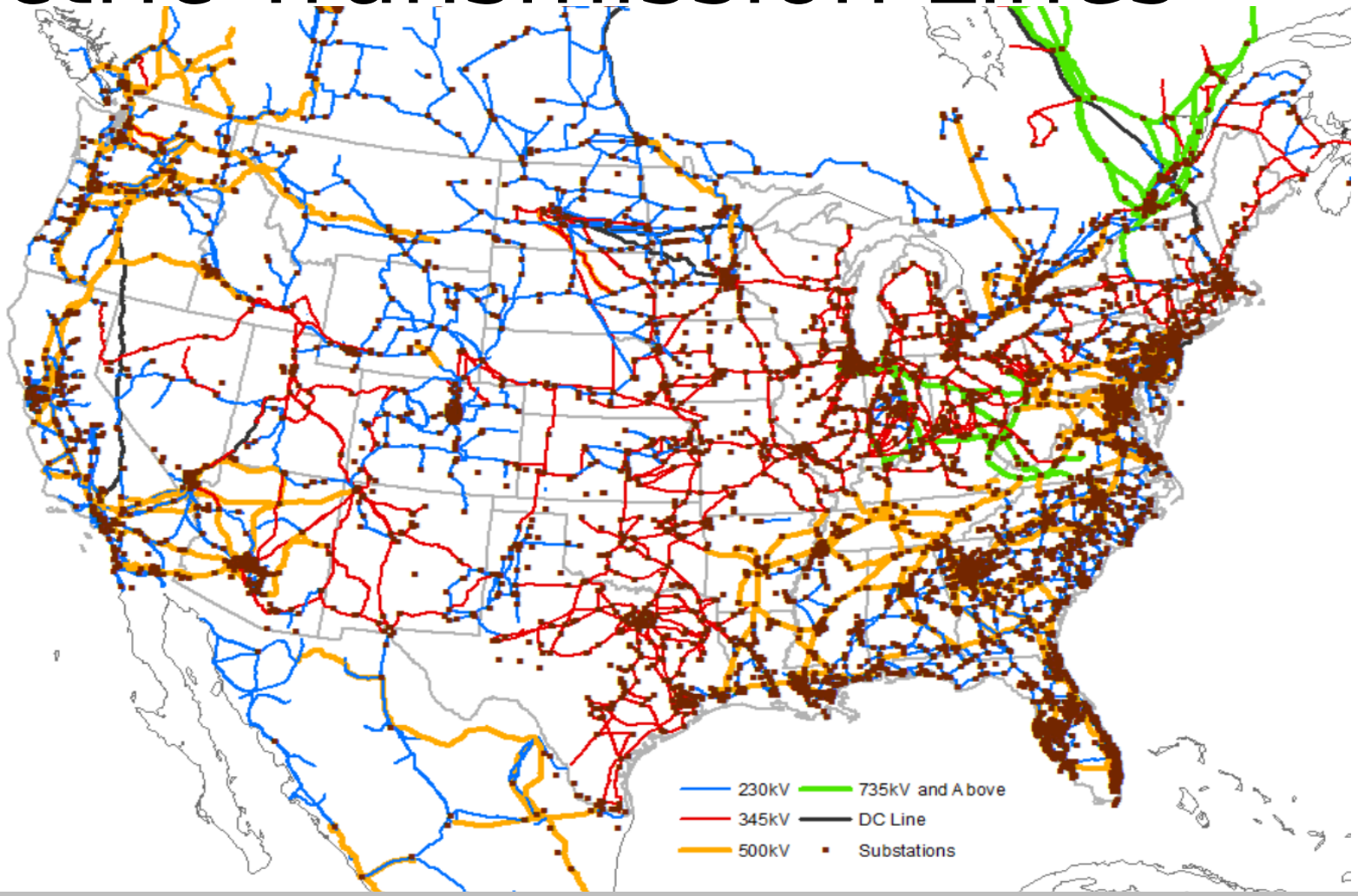
U.S. Electric Generation



U.S. Electric Transmission Lines



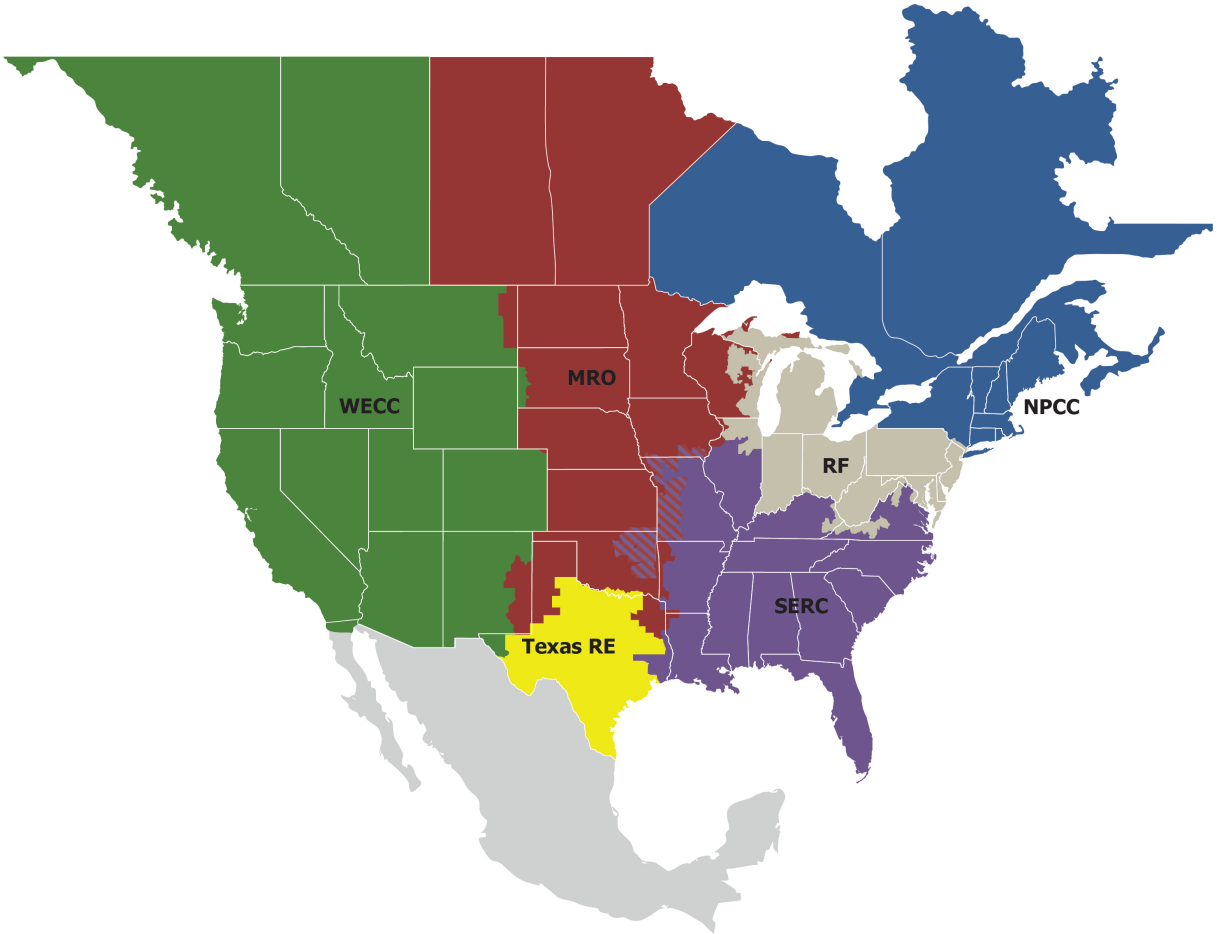
Electric Transmission Lines



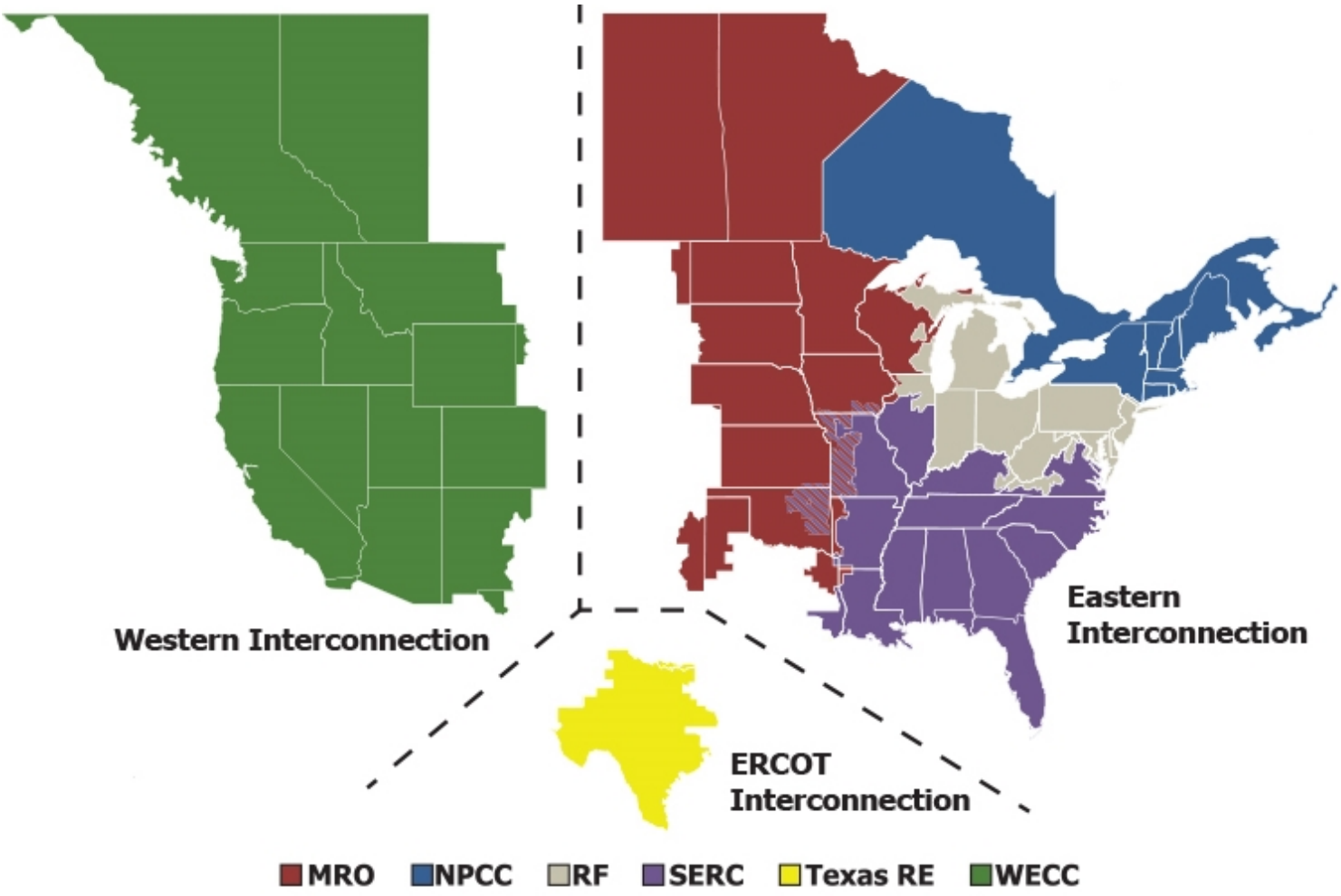
‘People in Charge’

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

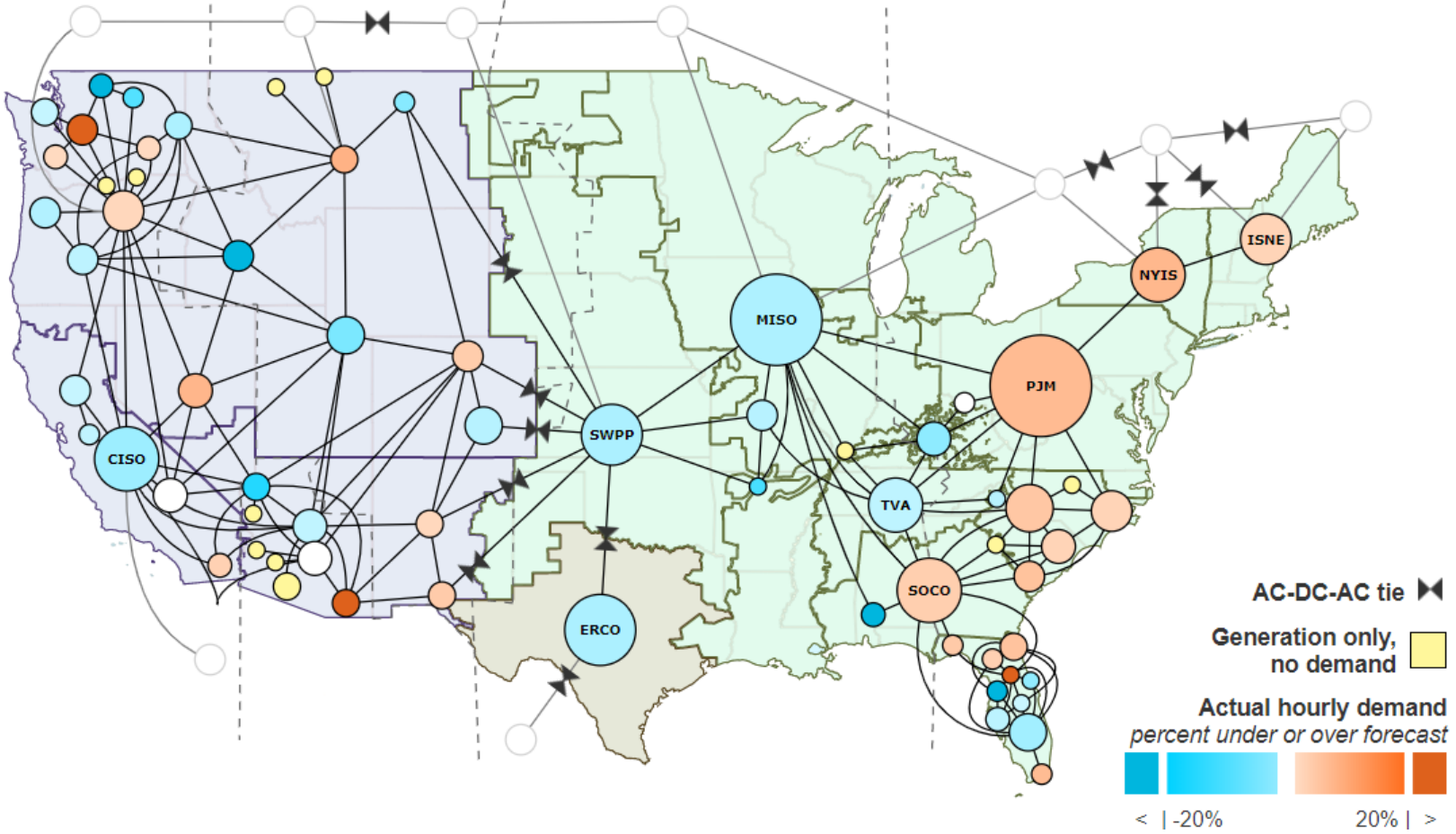
Six NERC Regions



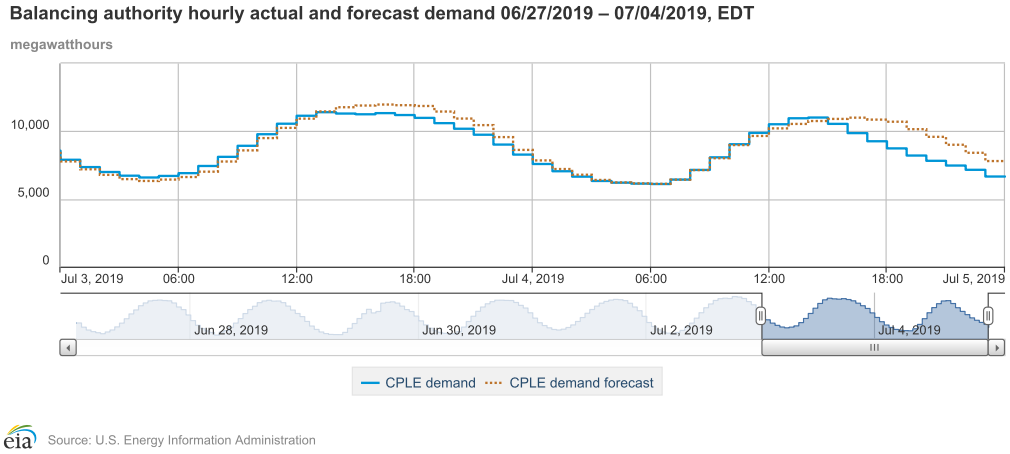
Main Interconnections

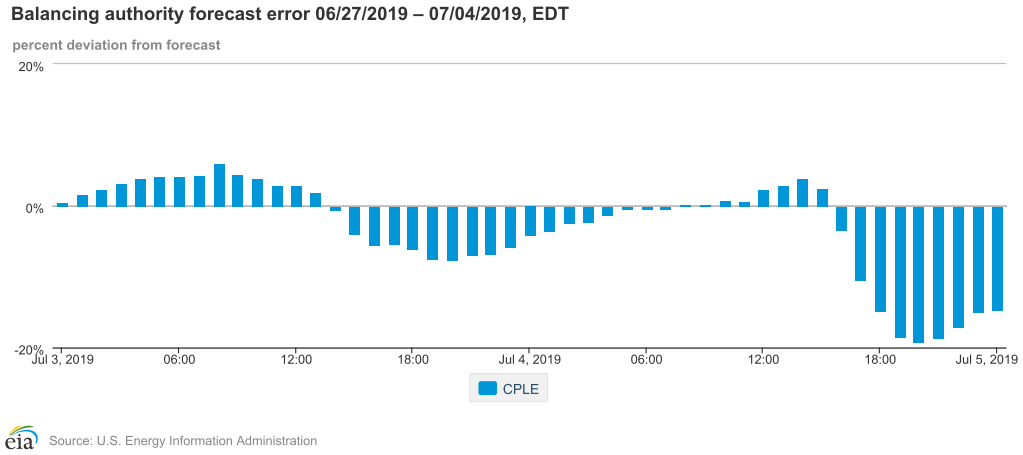


Balancing Authorities (BAs)

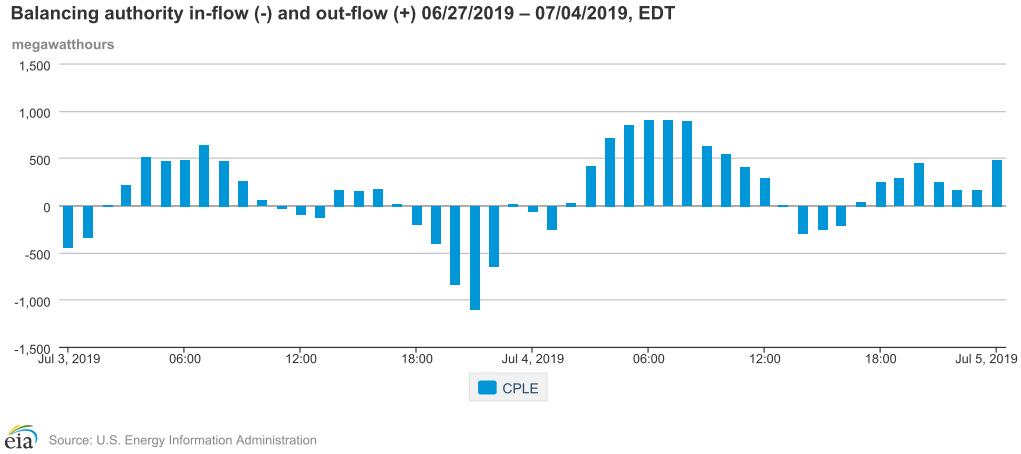


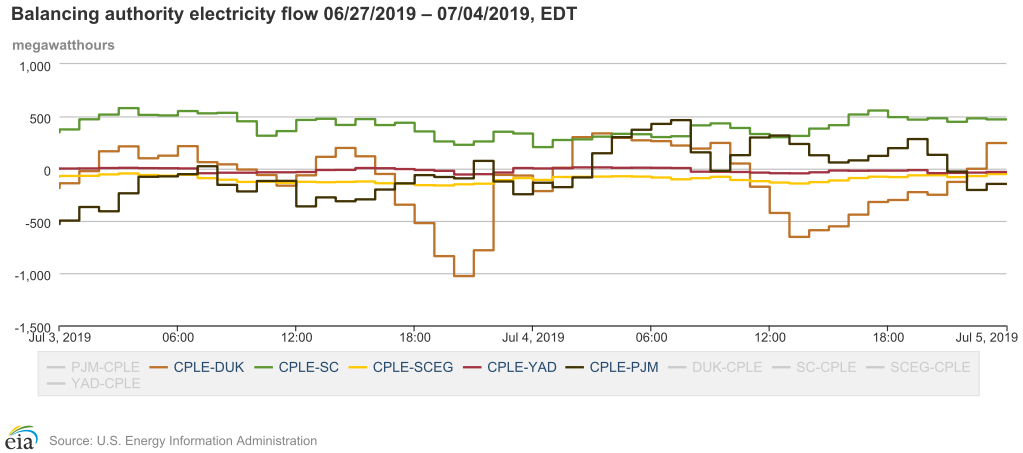
BA Action - Forcasting



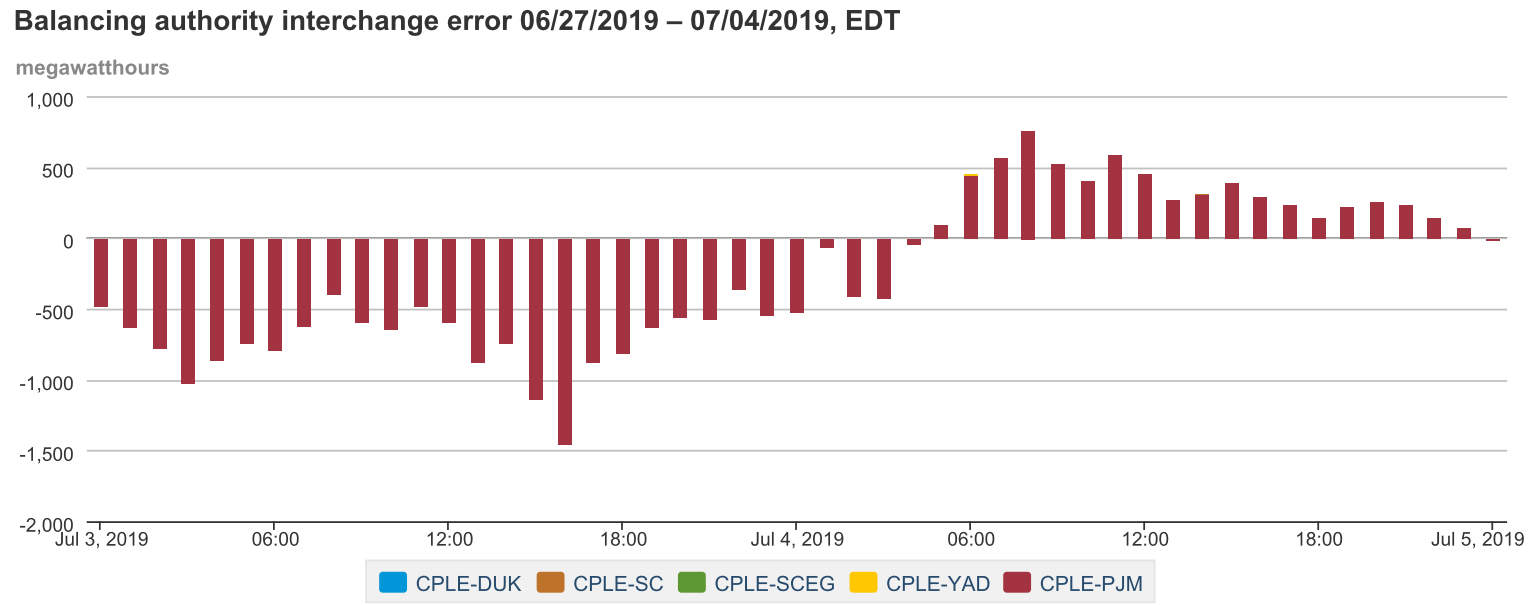


BA Action - Import & Export





BA Action - Interchange Error



eia Source: U.S. Energy Information Administration

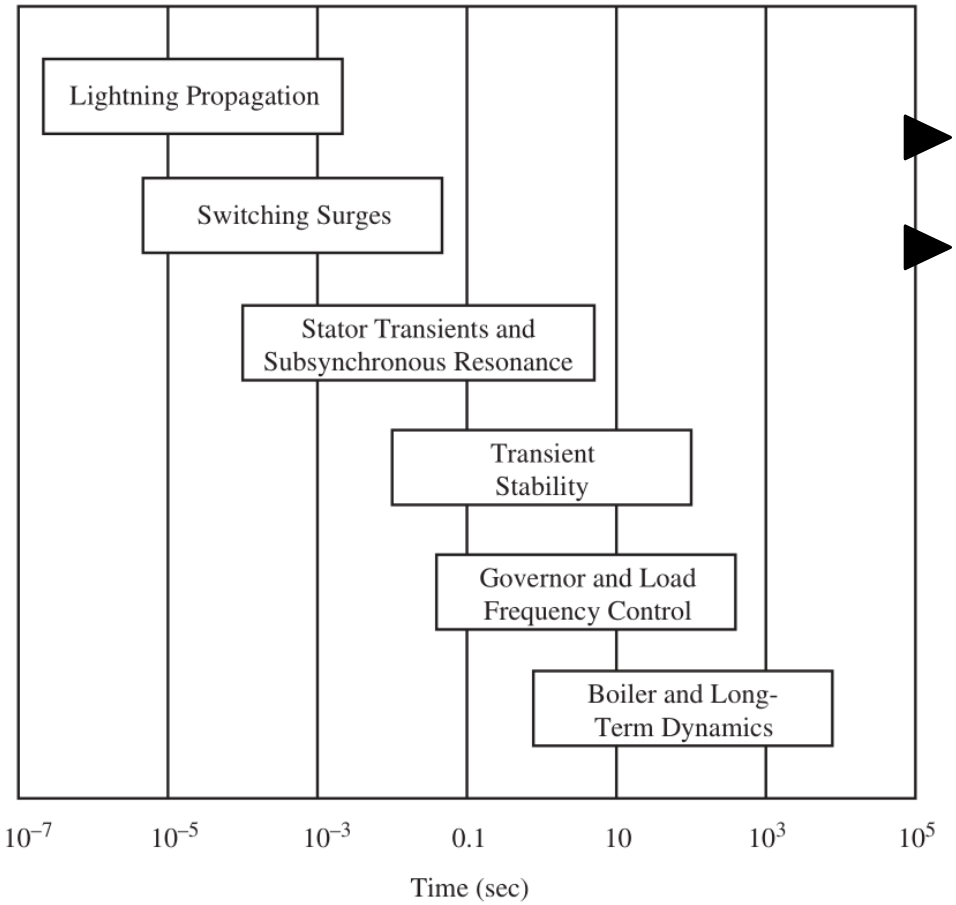
What is Dynamic Simulation?

A computer's mathematical estimation of how a system will change over time.

Think solving ODE's.

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

What is Long-Term?



[16]

- 1 sec time step
- 10-60 minute simulations

Generators

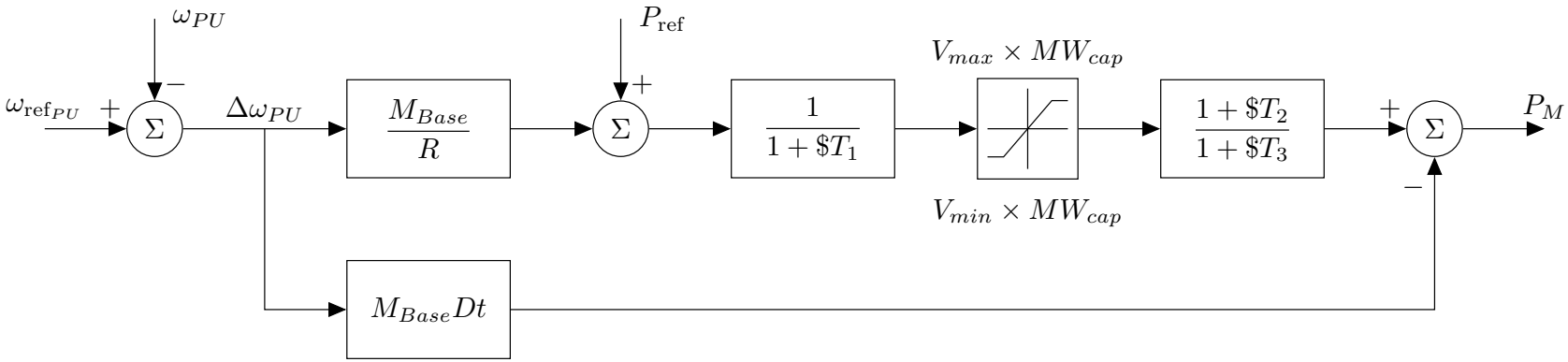
Frequency, Accelerating power and Inertia.

$$\dot{\omega}_{sys} = \frac{1}{2H_{sys}} \left(\frac{P_{acc,sys}}{\omega_{sys}(t)} - D_{sys} \Delta\omega_{sys}(t) \right)$$

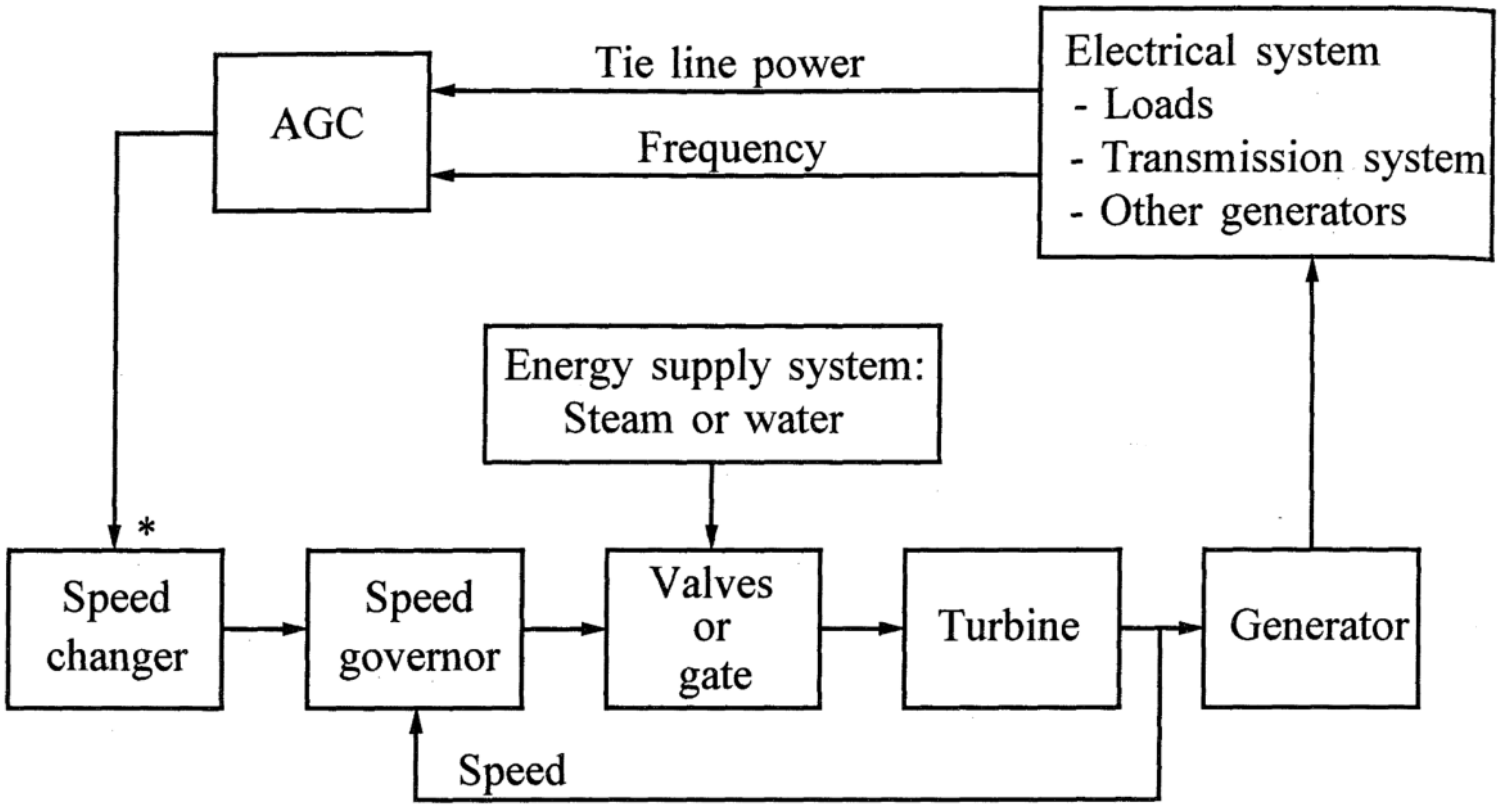
Direct link - electric demand always met. If there isn't enough generation, the kinetic energy stored as a moving inertia in a generator is converted to electric energy and the generator slows down.

Turbine Speed Governors

(Governors) Turbine speed governors adjust a machines mechanical power to stop frequency decline. Input is frequency deviation and current operating set point. Classified Primary control.



Automatic Generation Control



* AGC applied only to selected units

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Multi-Area Interactions

Areas import or export power to each other.

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 power system.

Power flows are do not care about time.

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, . . .)

Transient vs Long-Term Simulation

Time scale. Level of detail required. Equations - transient used ODE to find next steady state, LTD used ODE to find next guess of input to power flow.

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
  - Inadvertent Interchange
  - Turbine governor settings
  - Automatic Generation Control Settings
  - Governor and AGC interaction
- Ways to reduce Machine effort while meeting reliability standards.

Quick Initial Validation

pictures of step event comparisons of ltd vs psds

Quick Controller Test

BA controller action - do a with and without thing?

Current Conclusions

- Software (PSLTDSim) produces valid output for small to medium size systems.
- Governor and AGC interactions can happen easily
- Deadbands and conditional logic can be used to limit governor and AGC conflicts

Continuing Work

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

Questions?

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