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

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What is Long-Term?

Long-term describes the amount of time required for events of interest to occur and the simulation length to be executed.

In this case: 10 to 60 minutes

What is a Power System?

Electrical supply connected to demand.

Power plants connected via transmission lines to cities in different areas.

A part of ‘The Grid’.

What is Dynamic Simulation?

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

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

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, . . .)

So, what's happening?

Essentially:

- Executing computer simulations of the power grid 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.

Project Software Goals

- Develop software for (long-term dynamic) LTD simulations.
- Incorporate useful parts of GE software (PSLF):
  - Power Systems ($.sav$ files)
  - Dynamic model data ($.dyd$ files)
  - Power-flow solver
- Create simplified dynamic models compatible with LTD time steps.

Frequency, Accelerating power and Inertia.
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.

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

Automatic Governor Control Defined
(AKA Load Frequency Control)
Adjusts generator nominal operating set point to remove any inadvertent interchange and restore system frequency to 60 Hz. Secondary Control.

Multi Area Interactions
Areas import or export power to each other.

This simulation assumes:

1. Time steps of 0.5 to 1 second.
2. Fast dynamics are ’mostly’ ignored.
3. System remains synchronized.
4. System frequency is described by the combined PU swing equation:

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

5. No system damping $(D_{sys} = 0)$.

Software used:

- Python 3, IronPython
- Erlang / AMQP
- MATLAB

- Agent
  An autonomous individual object with properties and methods in a computer simulation.
- Agent-Based Modeling
  The idea that a system can be modeled using agents in an environment, and a description of agent-agent and agent-environment interactions. [2]

Current Conclusions

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

Continuing Work

- Further experiment with AGC and turbine speed governor settings
- Use valve travel and system reliability as engineering measuring sticks.

References

[1 GE Energy. "Mechanics of Running PSLF Dynamics" Phoenix, AZ, 2015

[2 Rand, W. (2018). Agent-Based Modeling: What is Agent-Based Modeling? [Online] Available: https://www.youtube.com/watch?v=FVmQbfsOkGc

[3 P.M. Anderson and A.A. Fouad, Power System Control and Stability, 2nd ed. IEEE Press, 2003, p20.

Questions?