

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

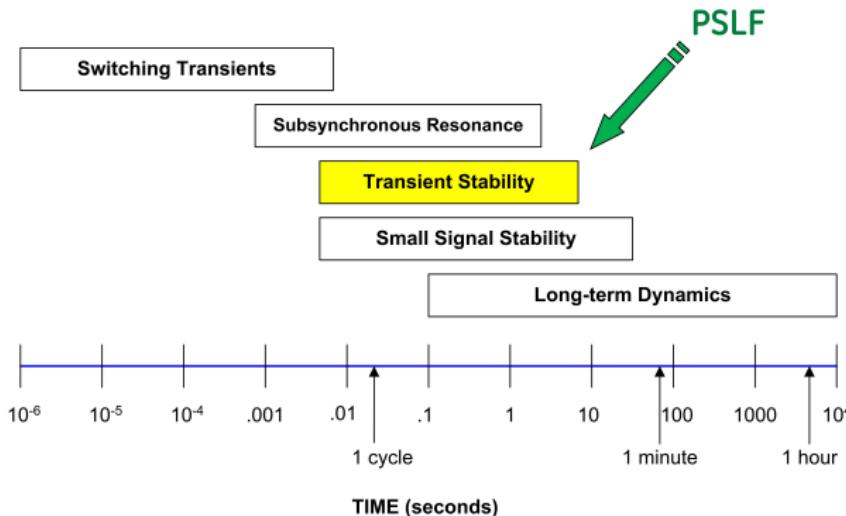
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Montana Tech - Master's Thesis Research Project

February 5th, 2019

What are long-term dynamics (LTD)? [1]

Power System Dynamic Time Scales



Overview of Project

Project Goals:

- ▶ Develop software for LTD simulations.
- ▶ Use PSLF:
 - ▶ Systems (.sav files)
 - ▶ Dynamic data (.dyd files)
 - ▶ Power-flow solver
- ▶ Create dynamic models compatible with LTD time steps.
- ▶ Investigate long-term events.
 - ▶ AGC
 - ▶ Wind ramps

Assumptions, Coding Decisions, Approaches, and Software Operation.

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 ($D_{sys} = 0$).

Assumptions, Coding Decisions, Approaches, and Software Operation.

Python will be used because:

- ▶ PSLF communication
- ▶ Free
- ▶ Community Libraries
- ▶ Object Oriented Programming
(Agent-Based Modeling)
- ▶ Scalability

Assumptions, Coding Decisions, Approaches, and Software Operation.

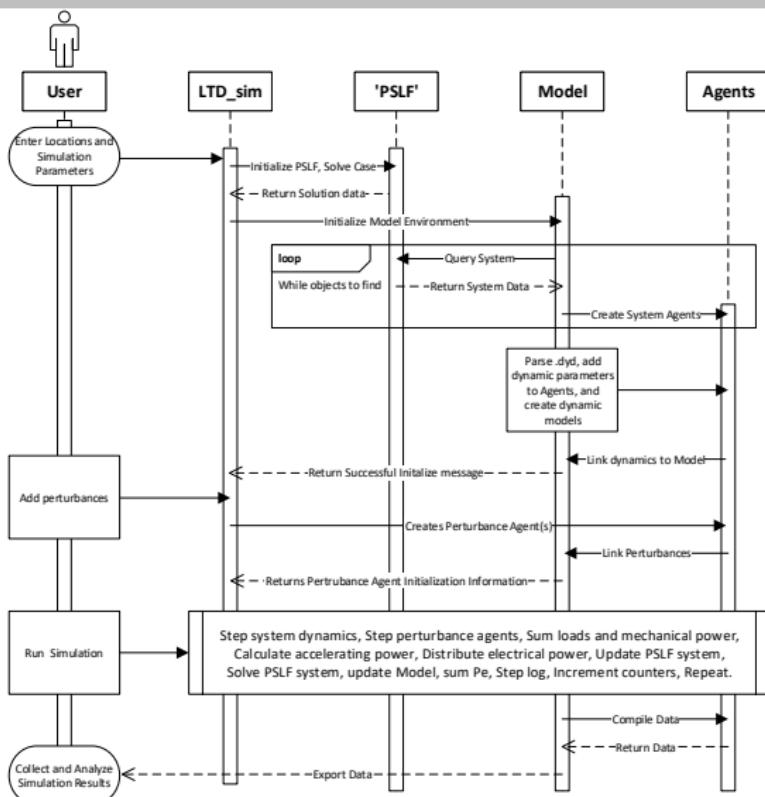
► Agent

An autonomous individual object with properties and methods in a computer simulation.

► Agent-Based Modeling

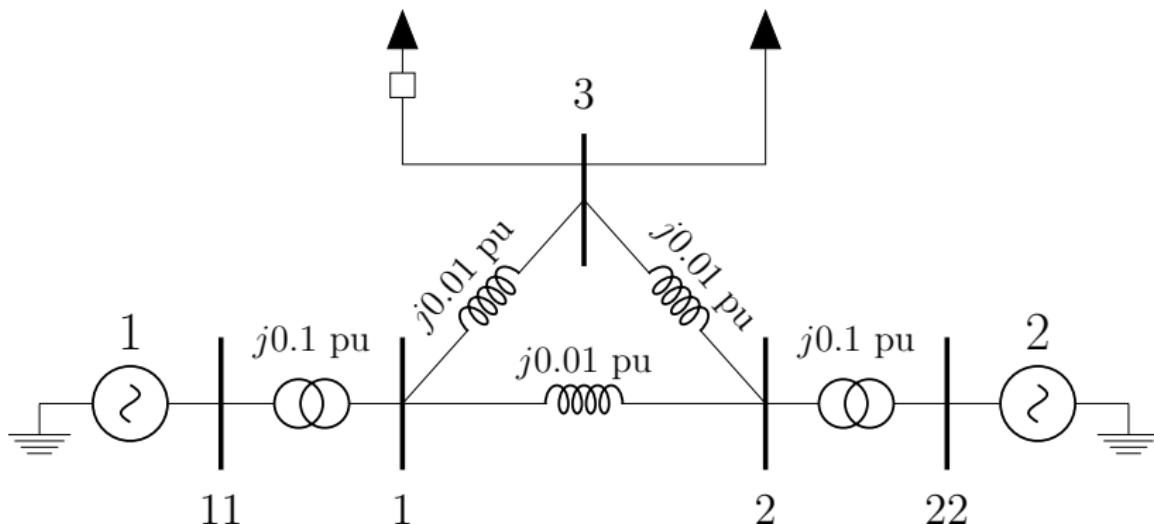
The idea that a system can be modeled using agents in an environment, and a description of agent-agent and agent-environment interactions. [2]

Assumptions, Coding Decisions, Approaches, and Software Operation.



System Used for Initial Frequency Validation and Proof of Concept.

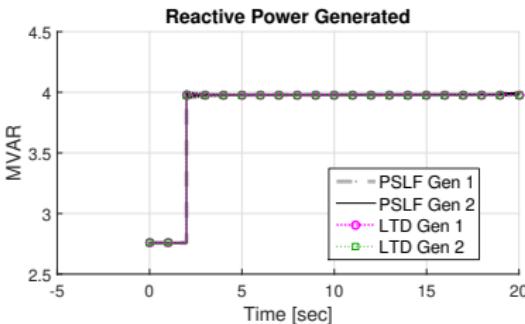
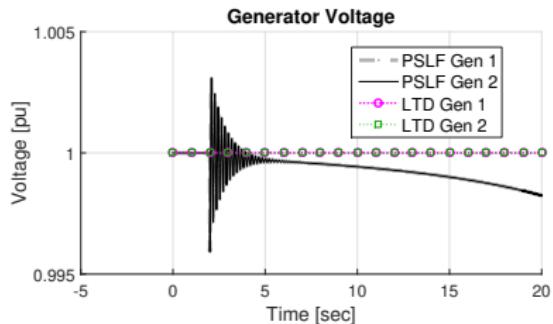
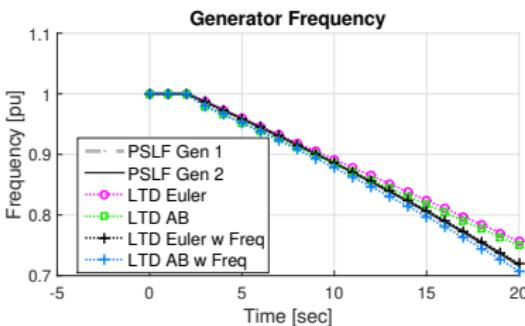
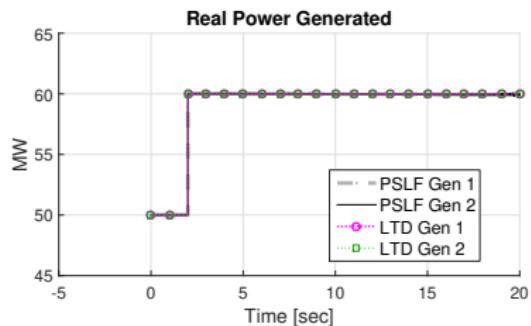
EE554.sav test system:



Generators are identical.
PSLF models have exciters.

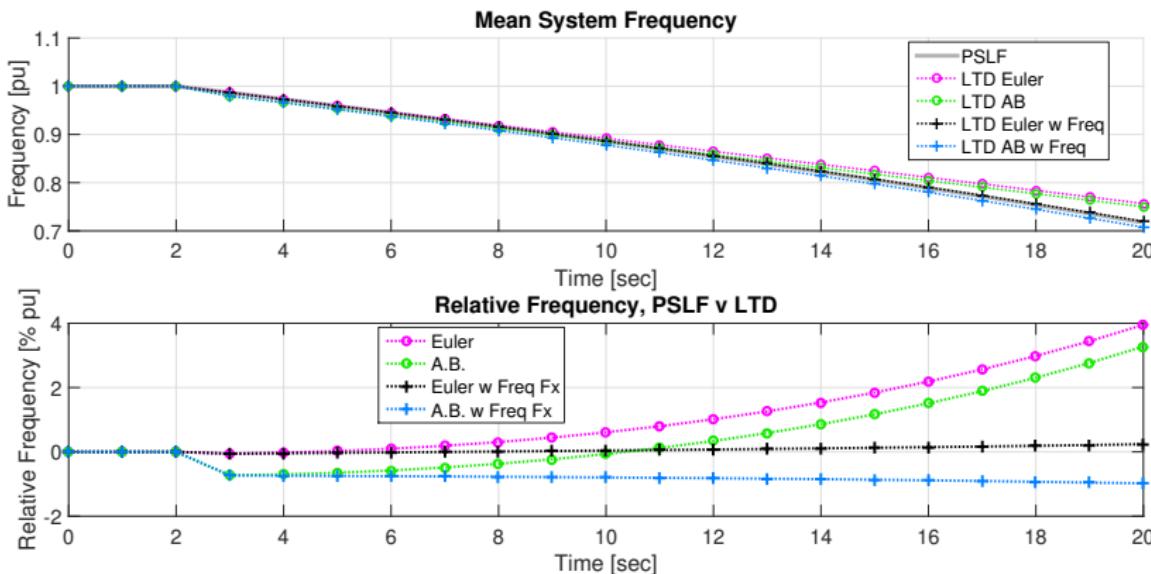
+20 MW Load Step at t=2

System Response



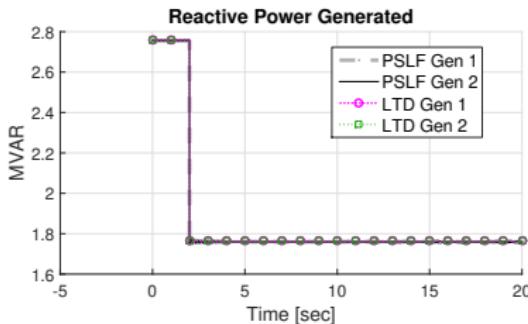
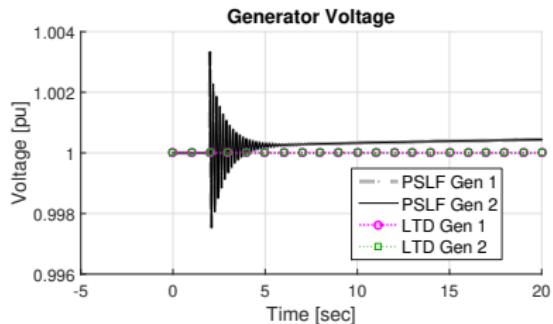
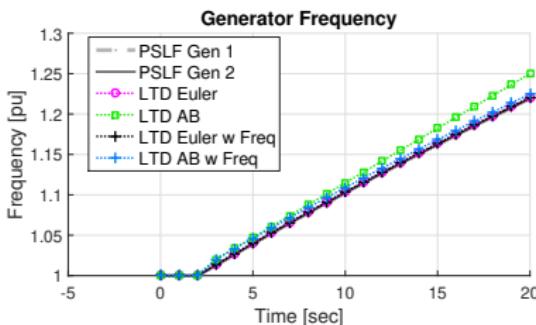
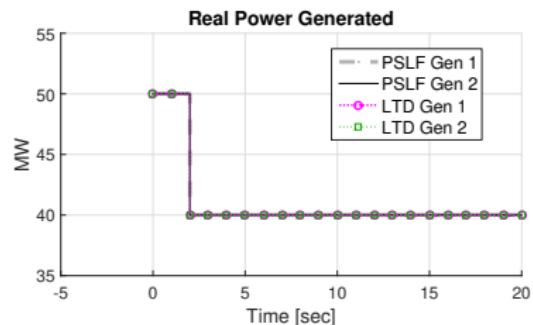
+20 MW Load Step at t=2

Detailed Frequency Response



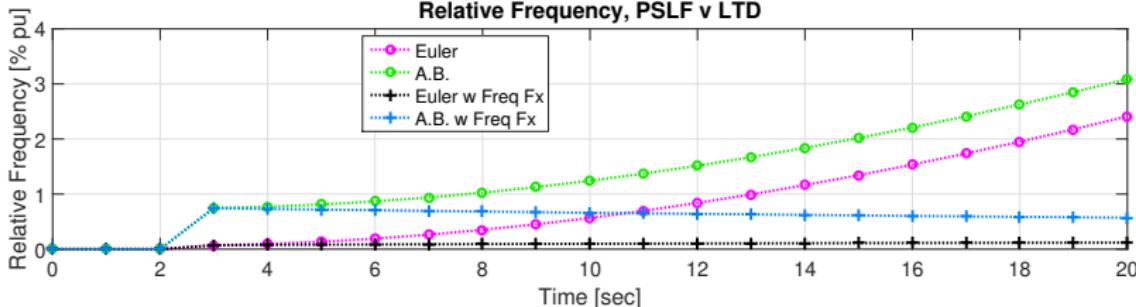
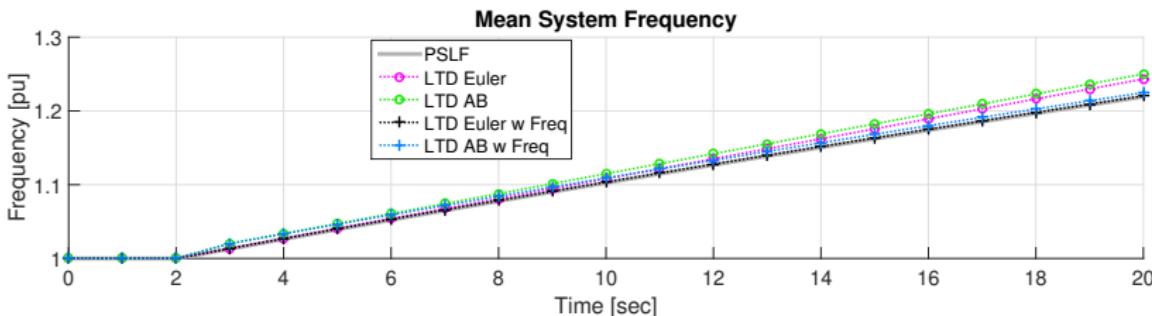
-20 MW Load Step at t=2

System Response



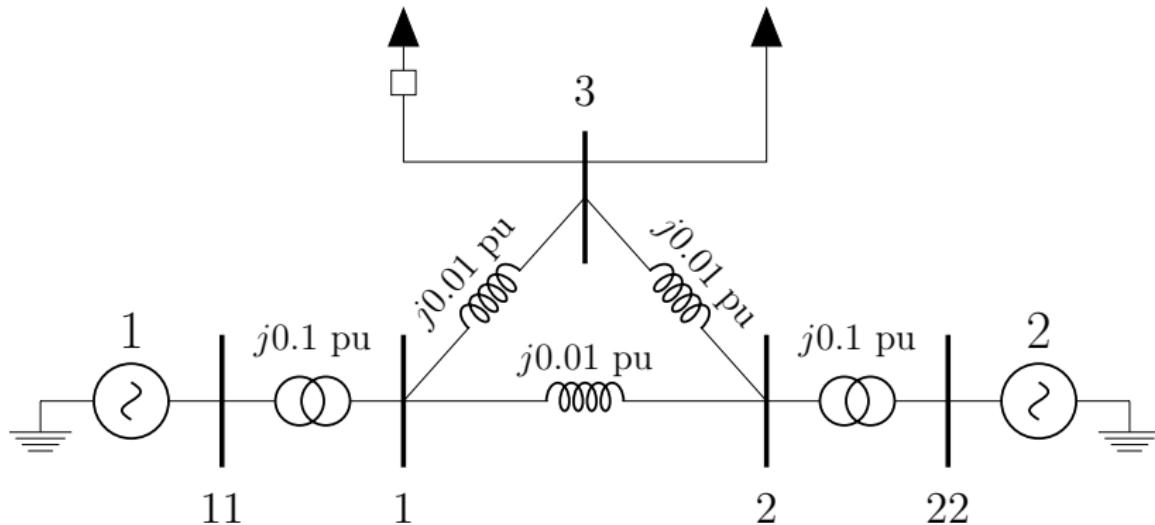
-20 MW Load Step at t=2

Detailed Frequency Response



Dynamic model testing, 'pgov1' defined

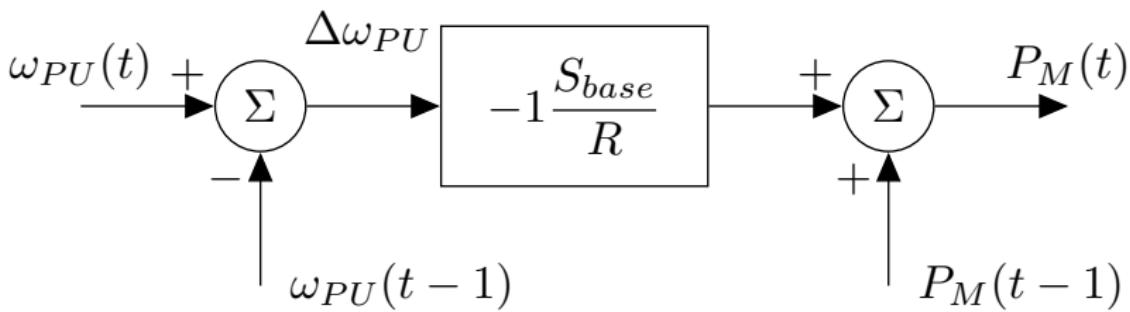
EE554.sav test system:



tgov1 added to PSLF .dyd file.

Dynamic model testing, 'pgov1' defined

pgov1 : Proportional gain control of P_M



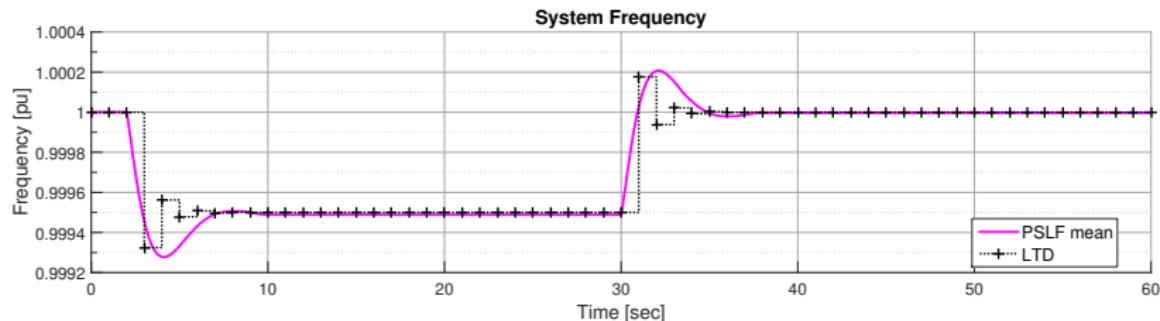
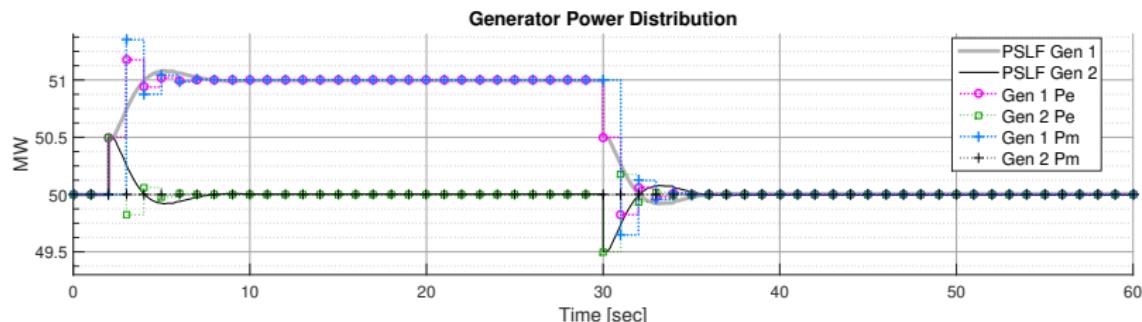
Entered into system via parsed text file:

```
# model busnum busnam basekv id : #9 mwcap droop
#!pgov1 11 "11" 22.00 "1" : #9 mwcap=100.0 0.05
```

Model adapted from [3]

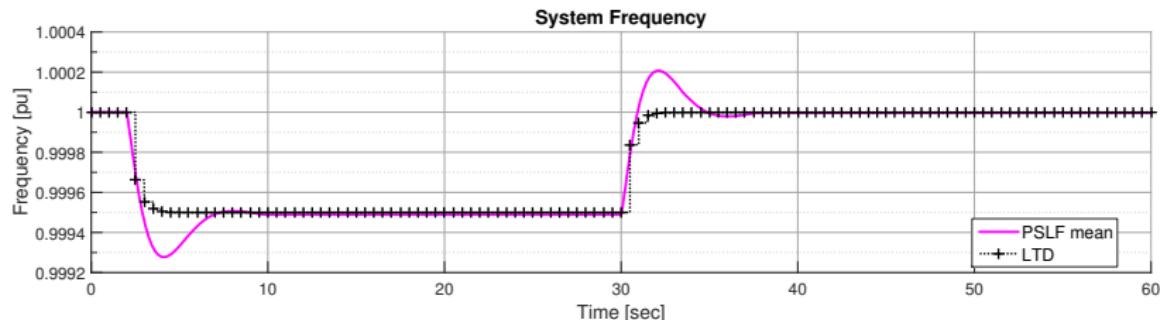
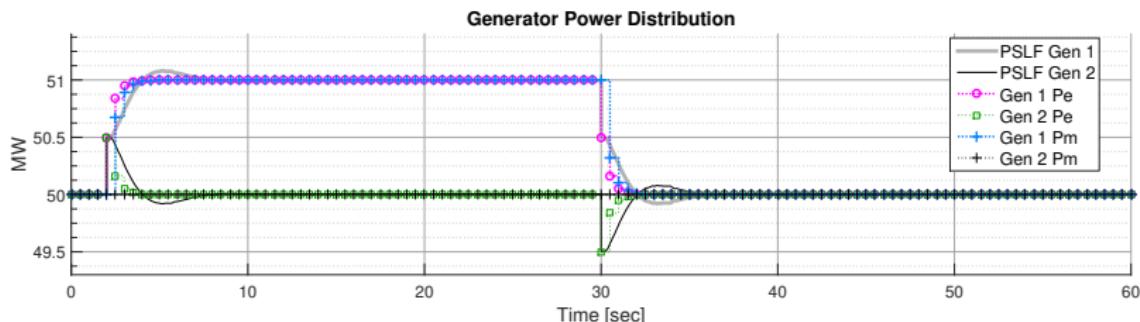
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

Governor on Gen 1, $t_{step} = 1.0$ second



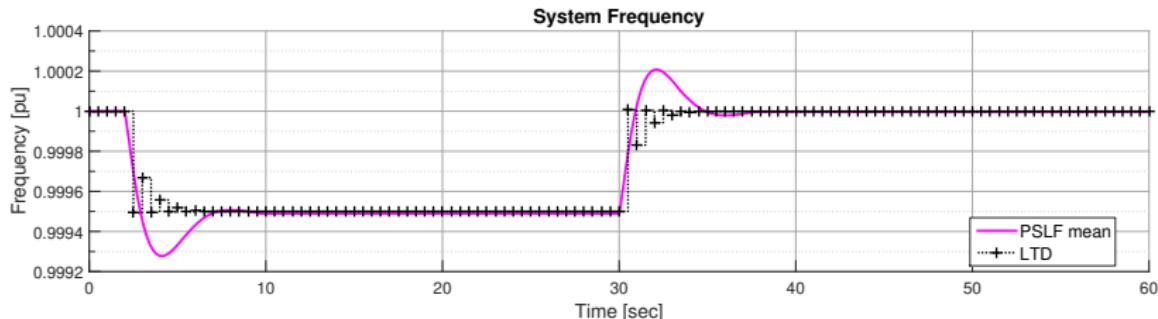
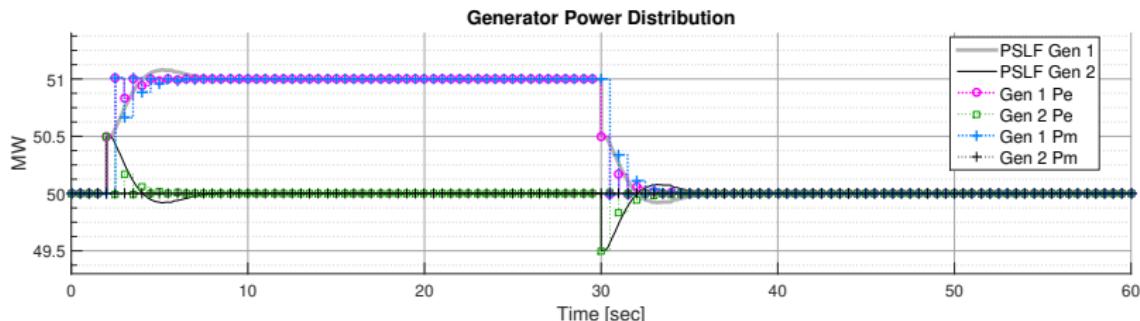
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

Governor on Gen 1, $t_{step} = 0.5$ second



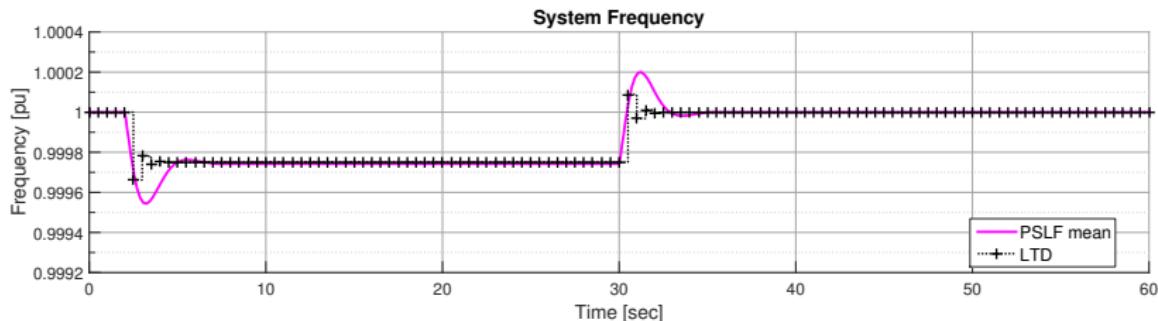
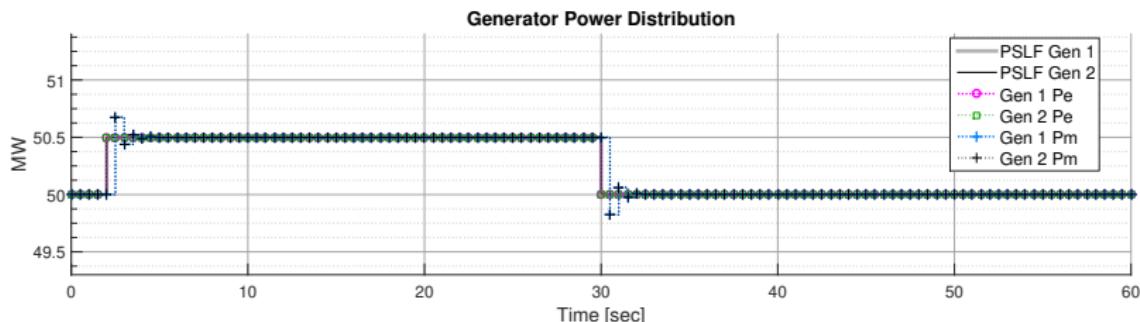
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

Governor on Gen 1, $t_{step} = 0.5$ second A.B.



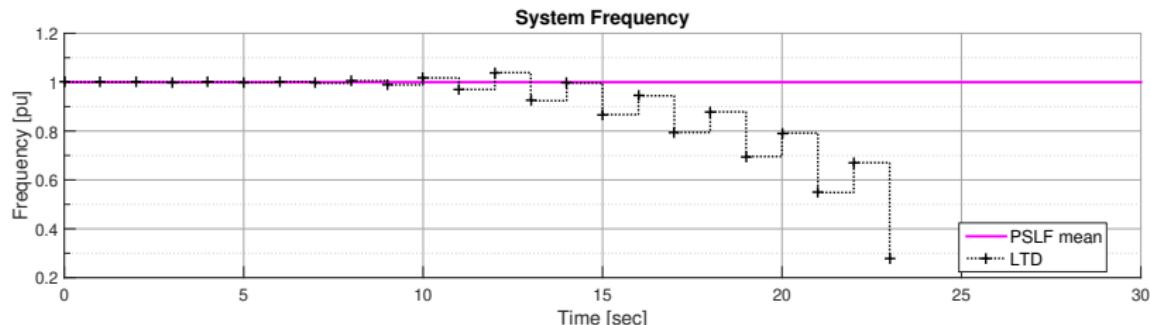
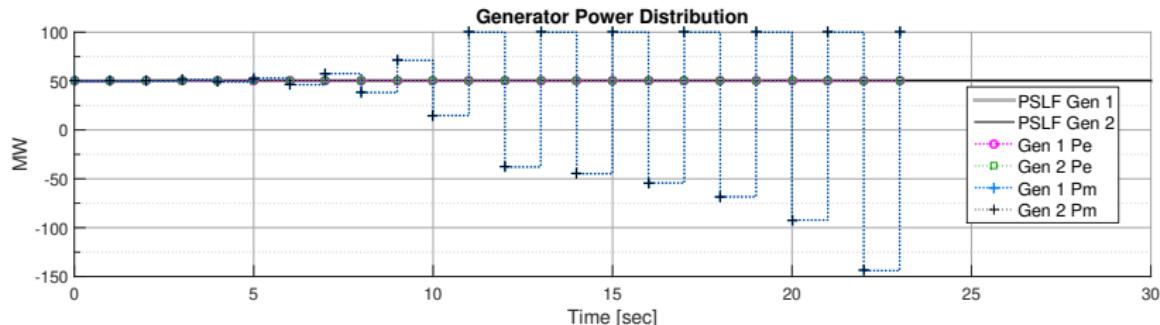
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

Governor on both Gens, $t_{step} = 0.5$ second



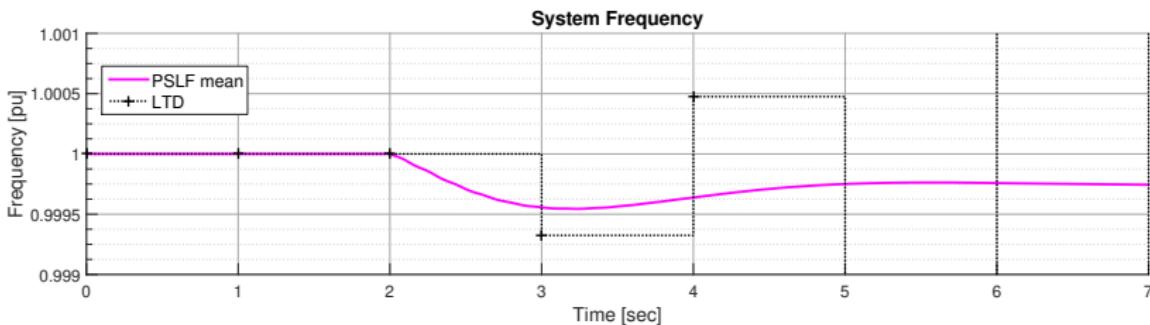
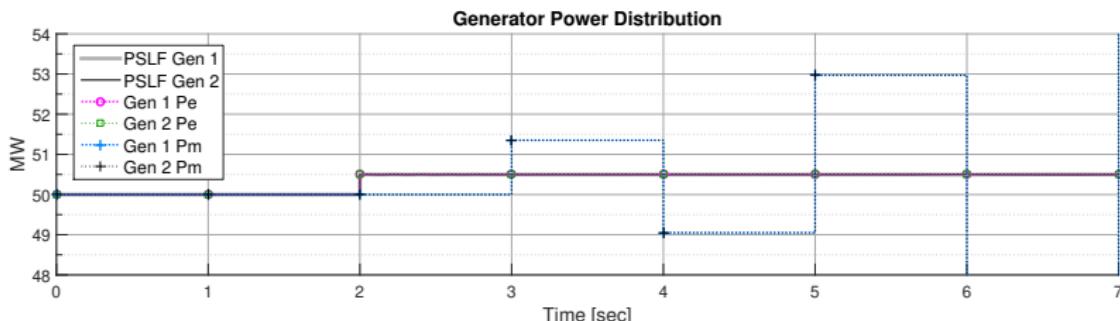
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

Governor on both Gens, $t_{step} = 1$ second



Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

Detail, $t_{\text{step}} = 1 \text{ second}$



Conclusions

- ▶ Frequency effects should be accounted for in swing equation.
- ▶ Euler Integration tracks PSLF mean frequency well.
- ▶ Custom dynamic model implementation seems realizable.

Future Work

- ▶ Incorporation of more PSLF objects into simulation.
- ▶ Creation of additional dynamic models and agents.
- ▶ Continue system and event testing and validation.

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