

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

Thad Haines

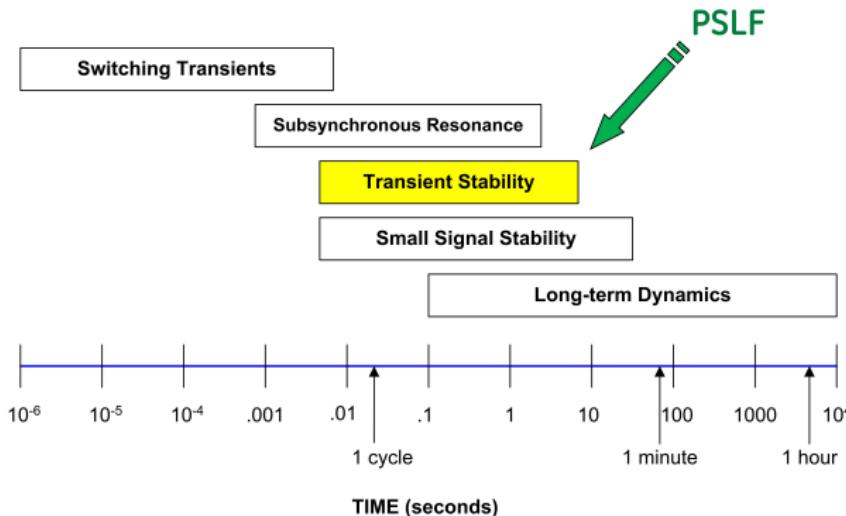
Montana Tech - Master's Thesis Research Project

February 5th, 2019

## Overview of Project

## 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)

Assumptions, Coding Decisions, Approaches, and Software Operation.

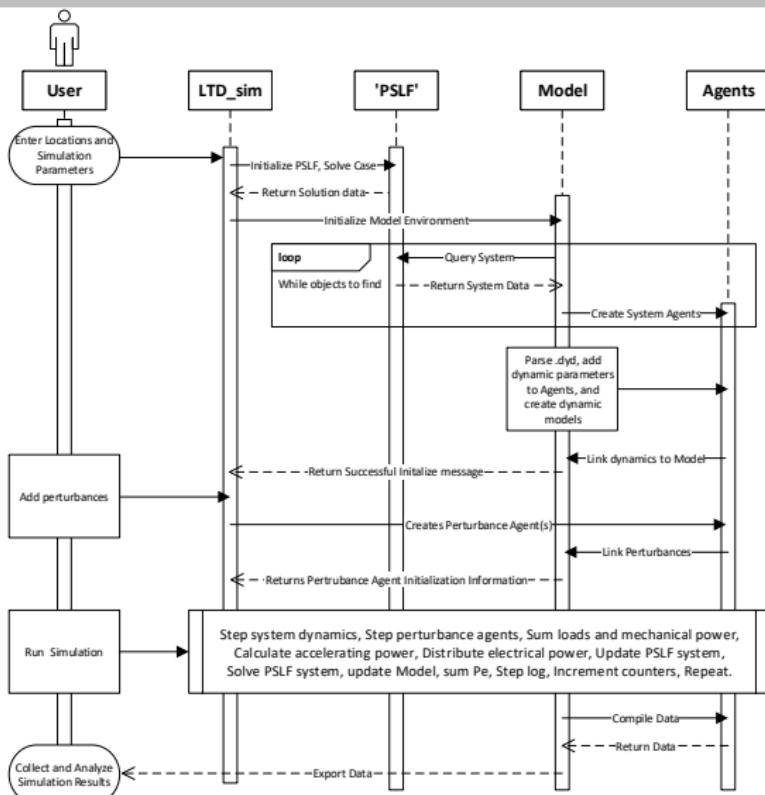
## ► Agent

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

## ► Agent-Based Modeling

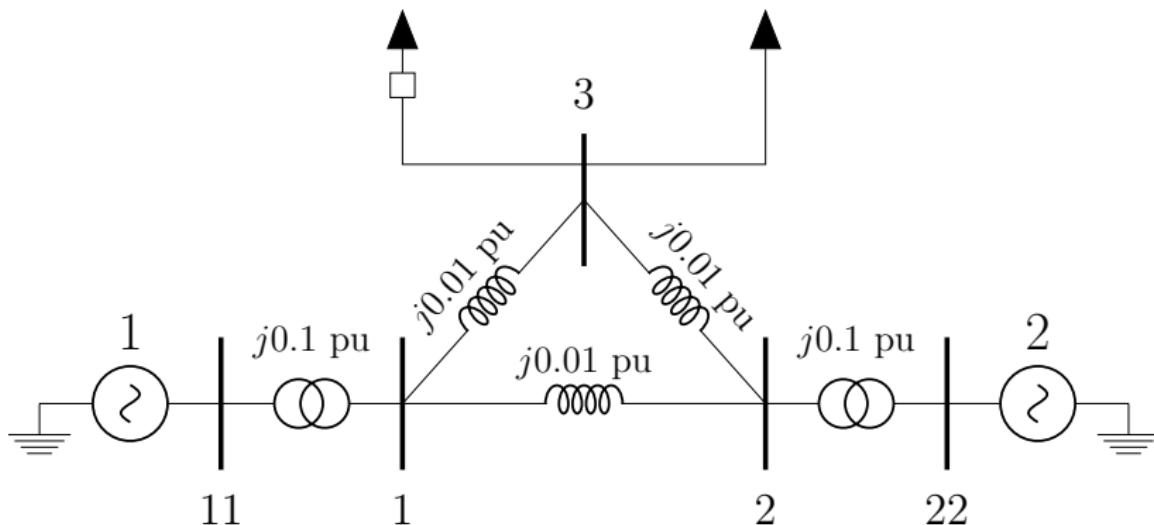
The idea that a system can be modeled using agents in an environment, and a description of agent-agent and agent-environment interactions. [2]

## Assumptions, Coding Decisions, Approaches, and Software Operation.



System Used for Initial Frequency Validation and Proof of Concept.

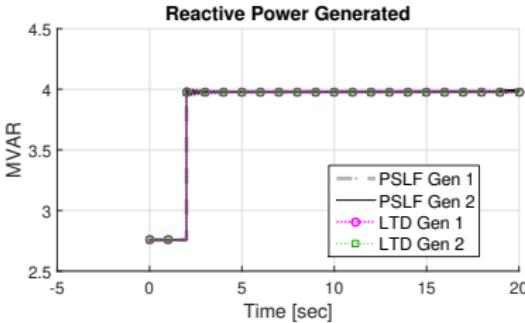
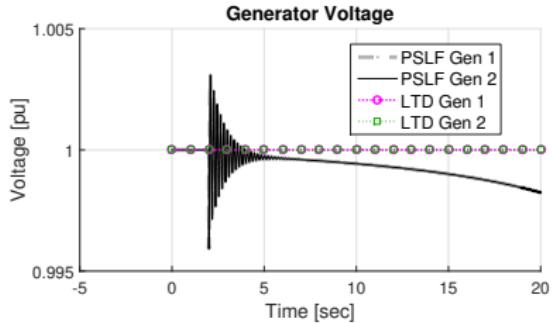
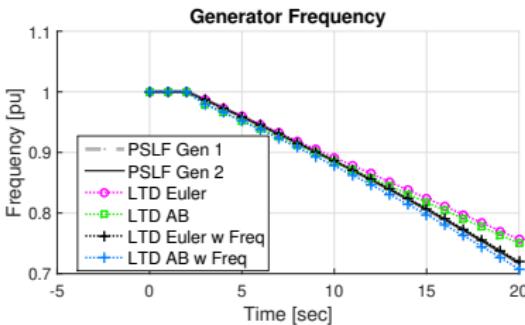
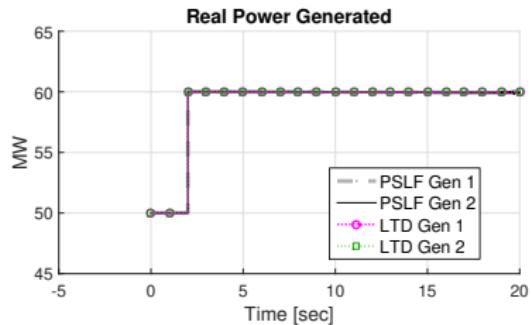
## EE554.sav test system:



Generators are identical.  
PSLF models have exciters.

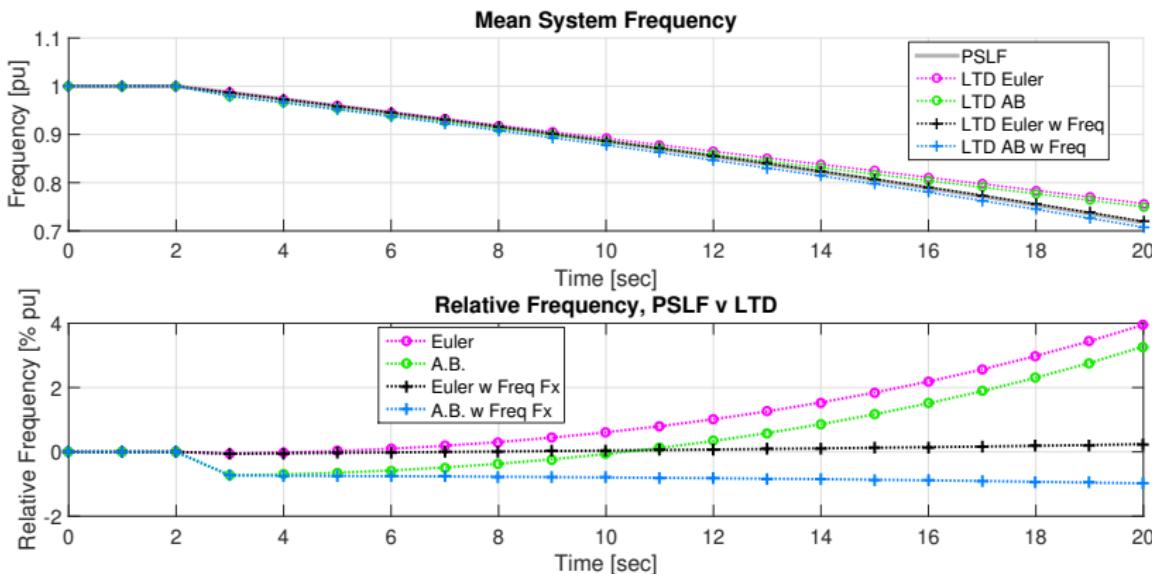
+20 MW Load Step at t=2

# System Response



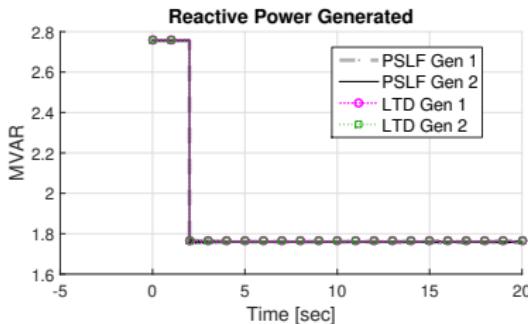
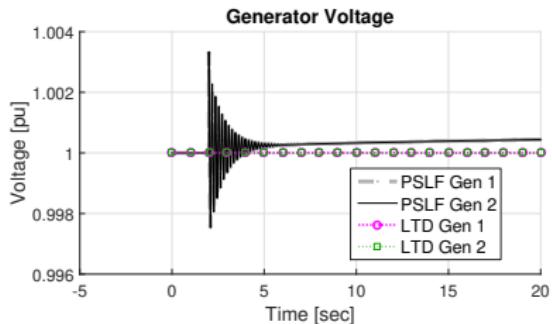
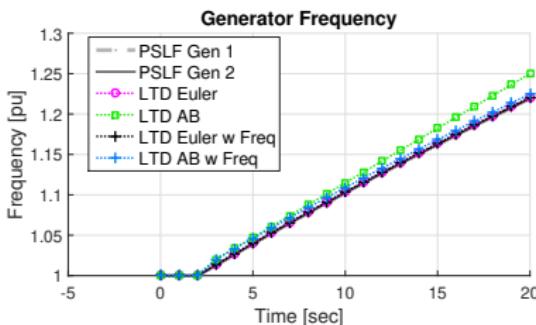
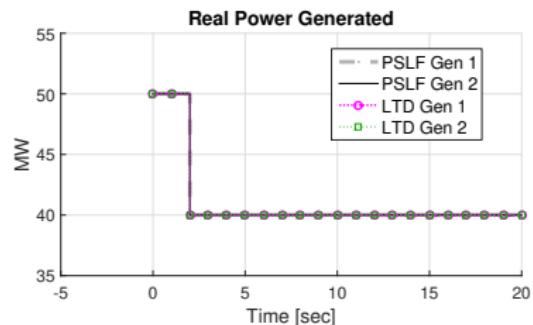
+20 MW Load Step at t=2

# Detailed Frequency Response



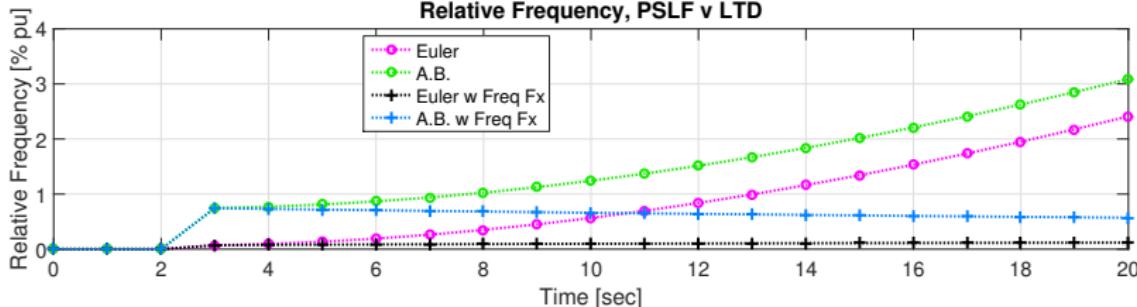
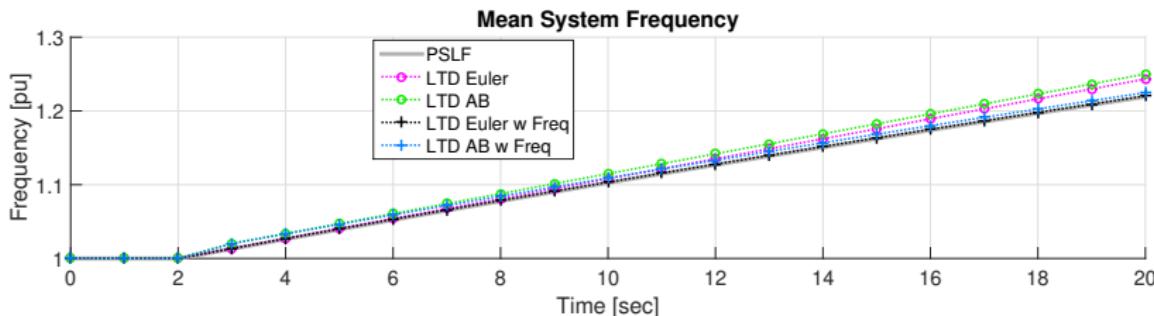
-20 MW Load Step at t=2

# System Response



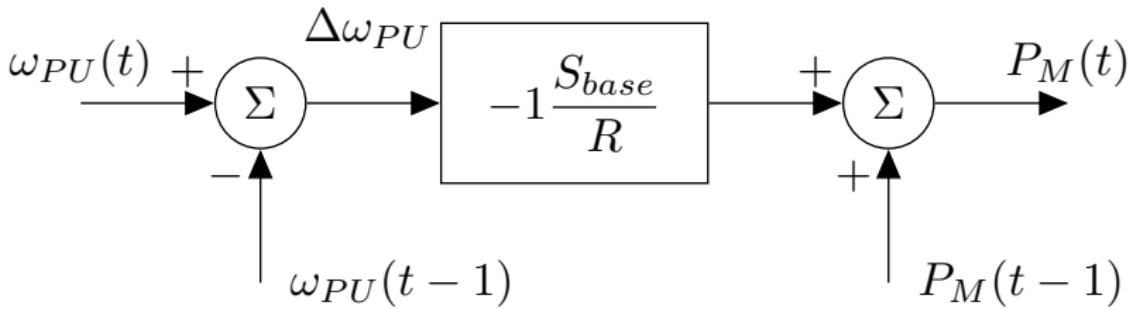
-20 MW Load Step at t=2

# Detailed Frequency Response



Dynamic model 'pgov1' defined

## pgov1 : Proportional gain control of $P_M$



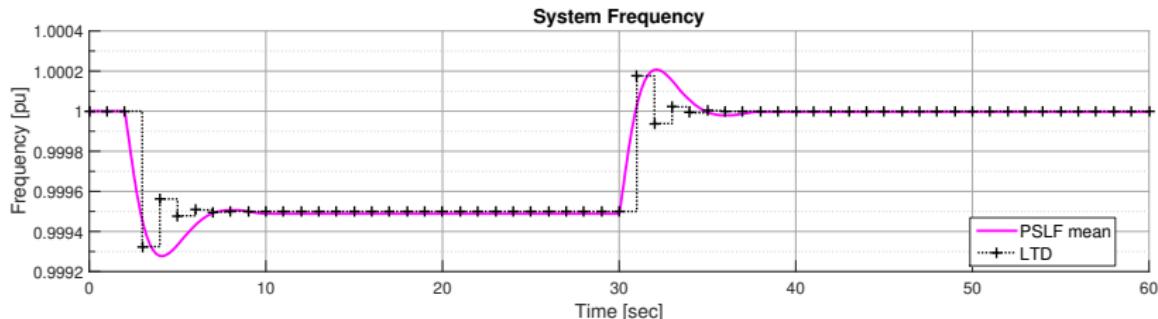
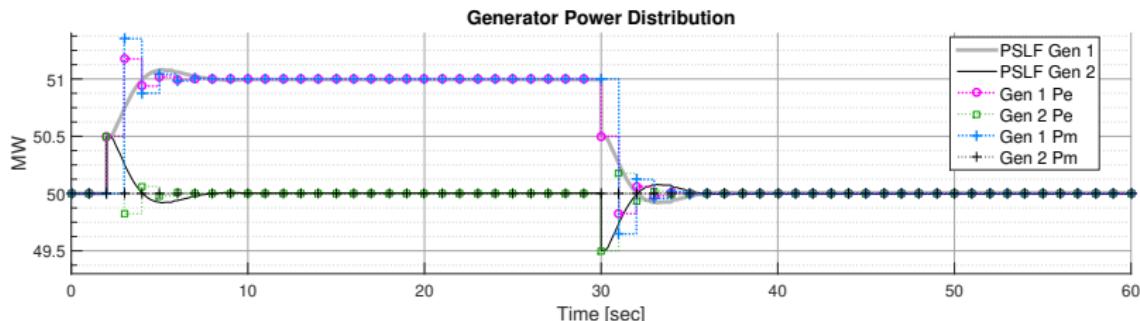
Entered into system via parsed text file:

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

Model adapted from [3]

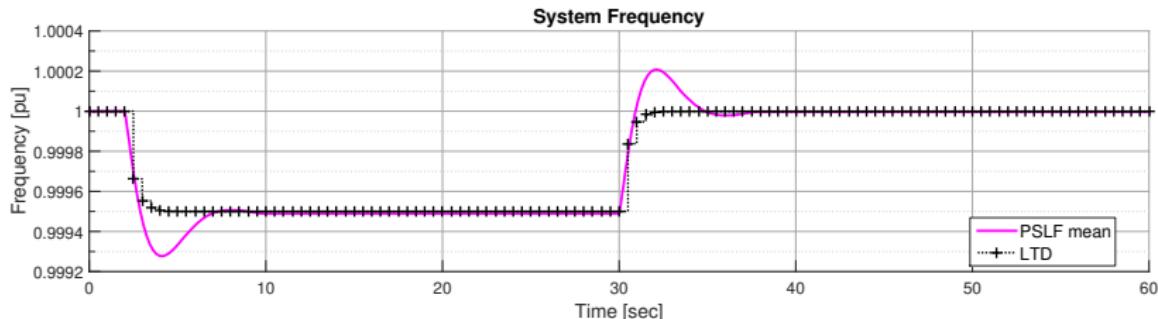
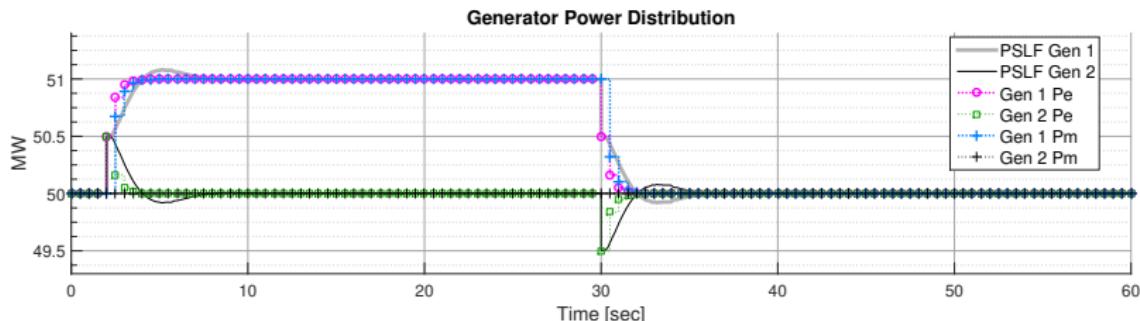
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

# pgov1 on Gen 1, $t_{step} = 1.0$ second



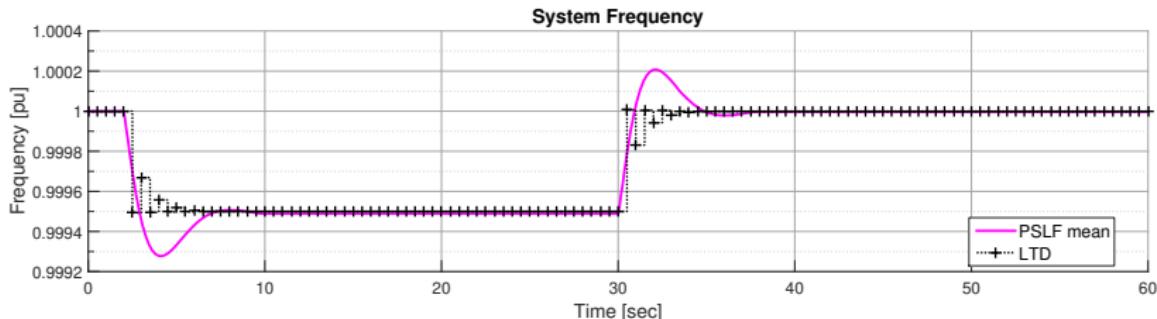
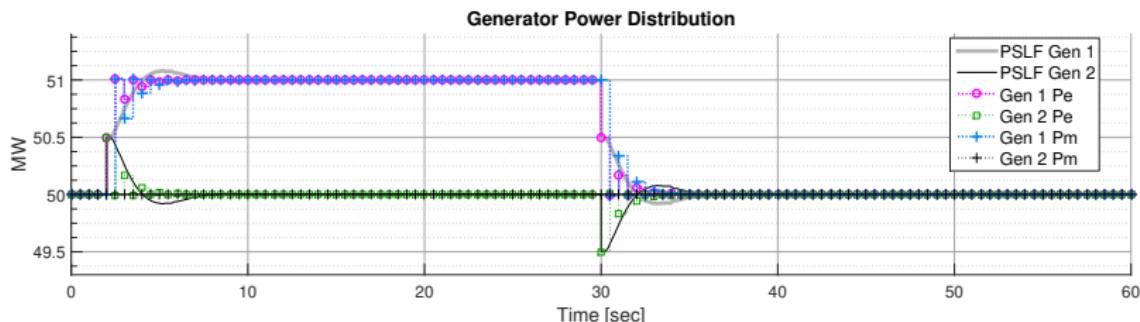
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

# pgov1 on Gen 1, $t_{step} = 0.5$ second



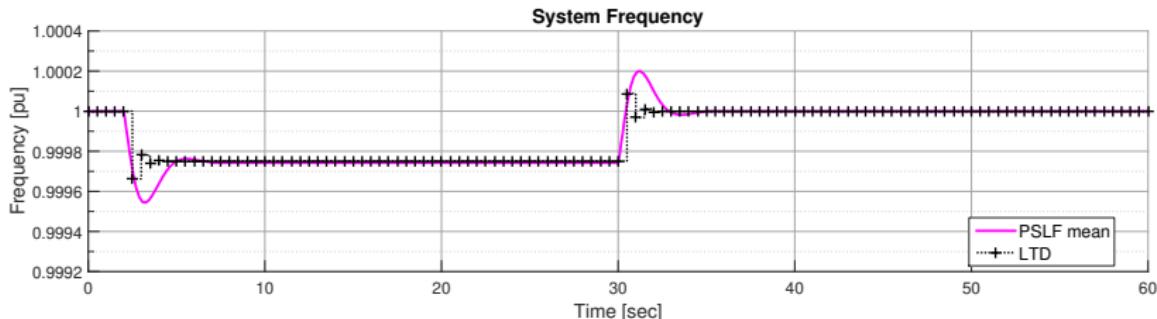
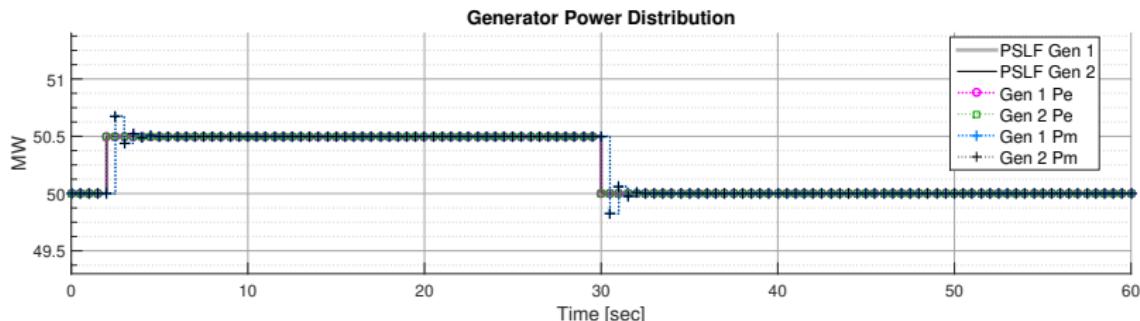
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

# pgov1 on Gen 1, $t_{step} = 0.5$ second AB



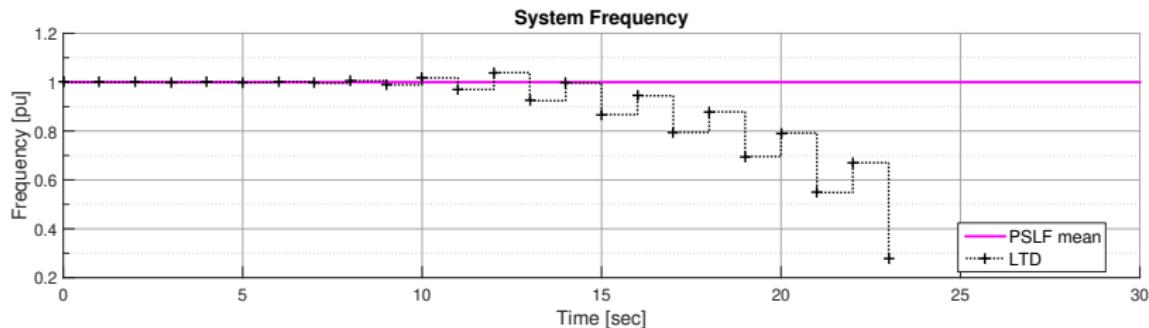
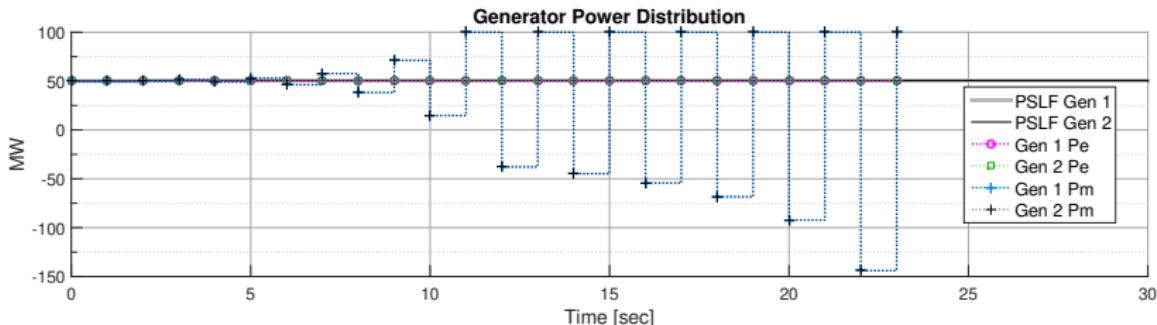
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

# pgov1 on both Gens, $t_{step} = 0.5$ second



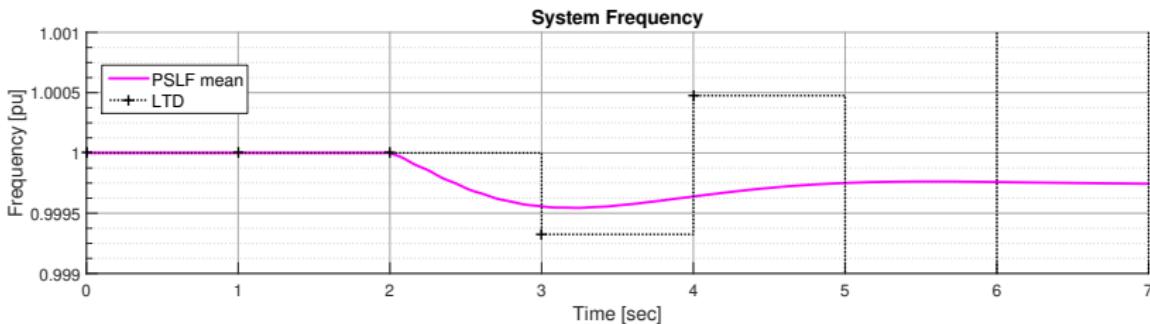
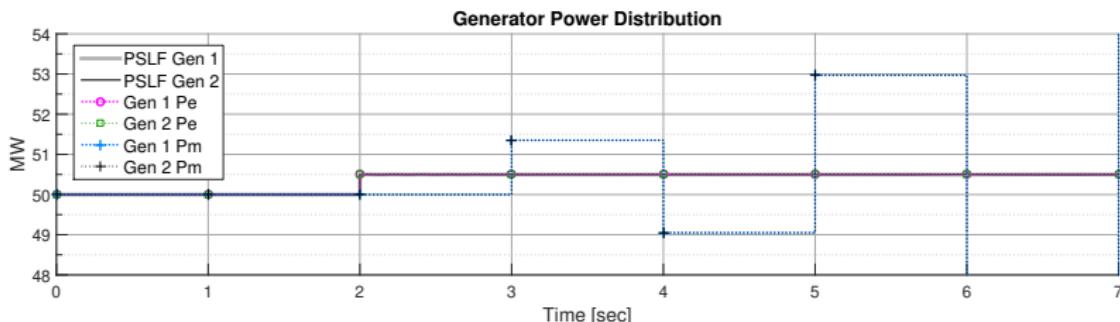
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

## pgov1 on both Gens, $t_{step} = 1$ second



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

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



- ▶ Much more work to do.

However,

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

# 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.