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

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Montana Tech - Master's Thesis Research Project

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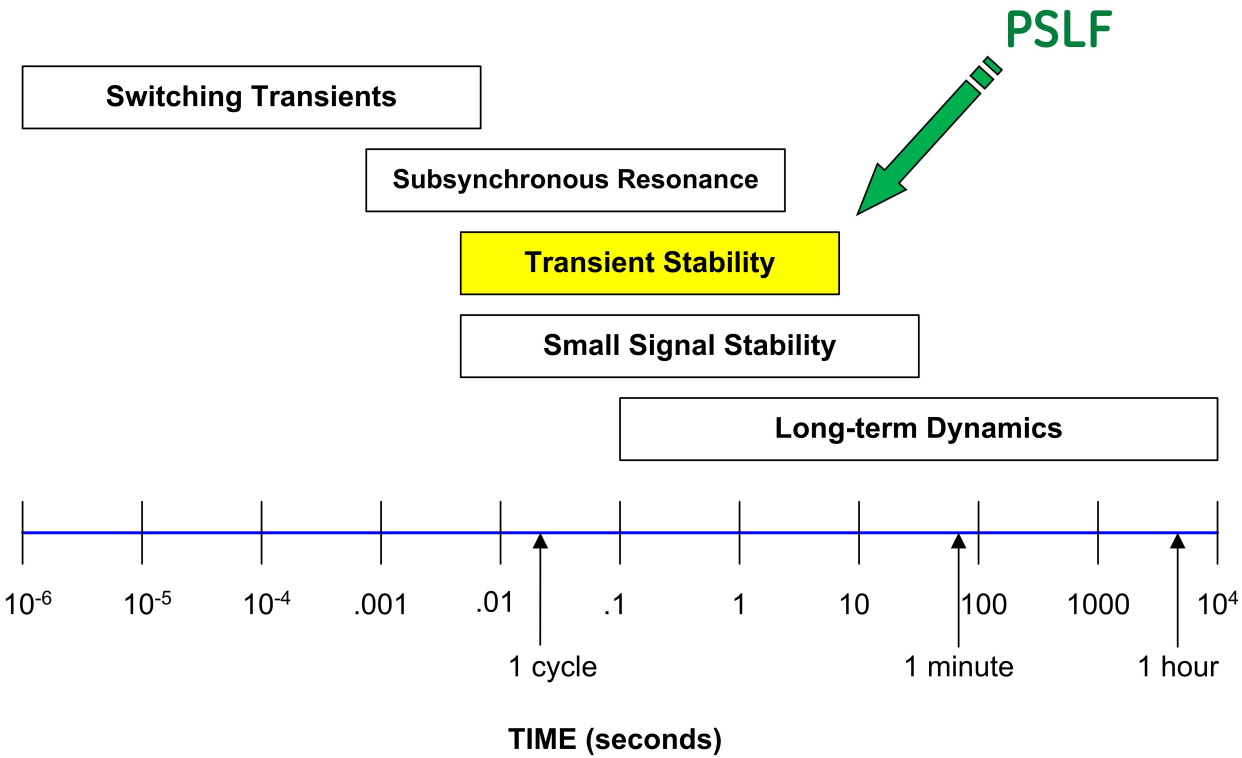
What are long-term dynamics (LTD)? [1]

Power System Dynamic Time Scales



This simulation assumes:

1. System remains stable.
2. System frequency is described by the combined PU swing equation:

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

3. No system damping $(D_{sys} = 0)$.
4. Time steps of 1 or 0.5 seconds.
5. Fast dynamics are 'mostly' ignored.

Project Goals:

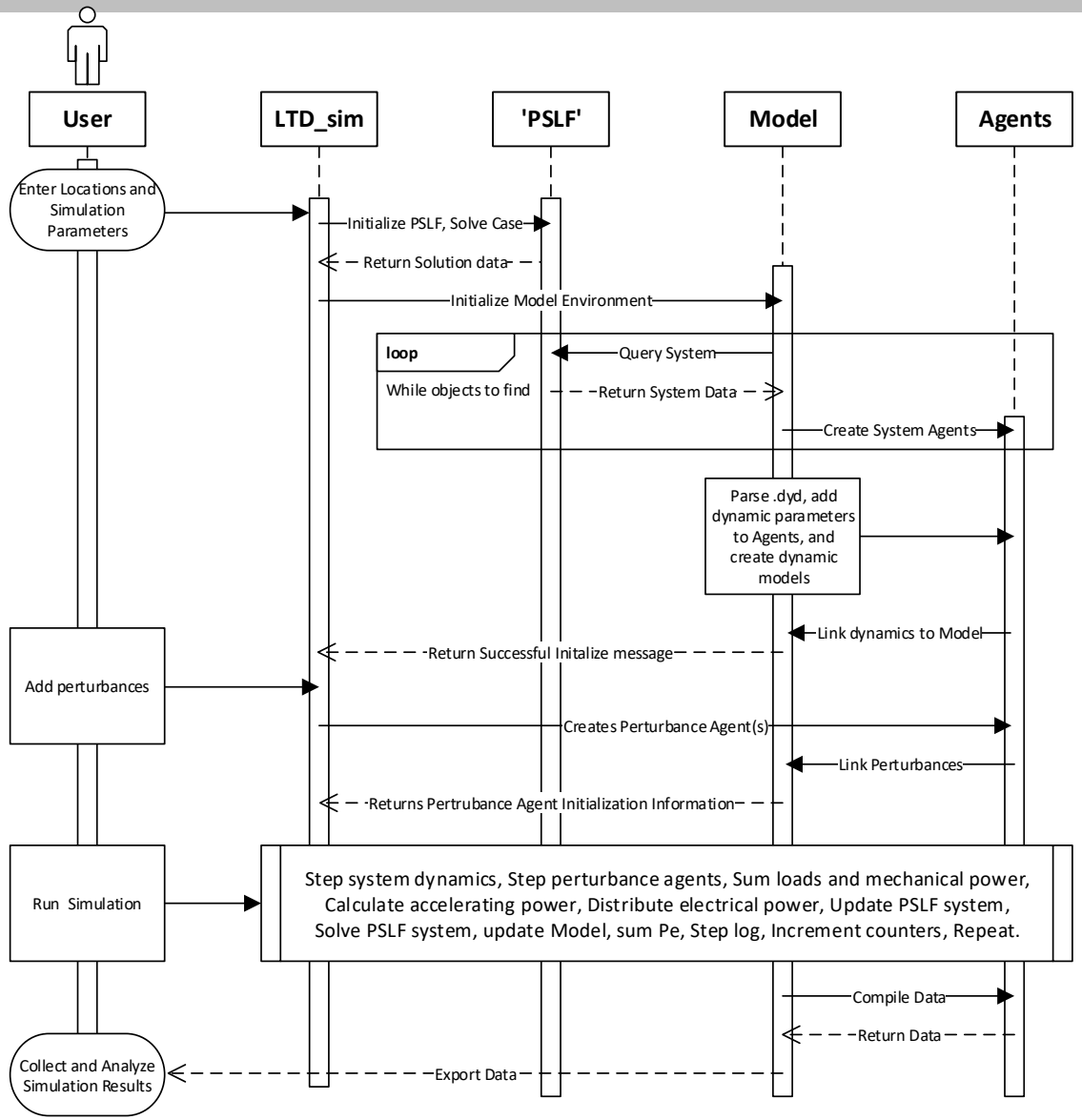
- Develop computer software for LTD simulations using PSLF systems $(.sav)$, dynamic data $(.dyd)$, and customized dynamic models.
- Use software to investigate system reactions that may be impractical to simulate using other approaches.
- Write a master's thesis about it.

Python will be used because:

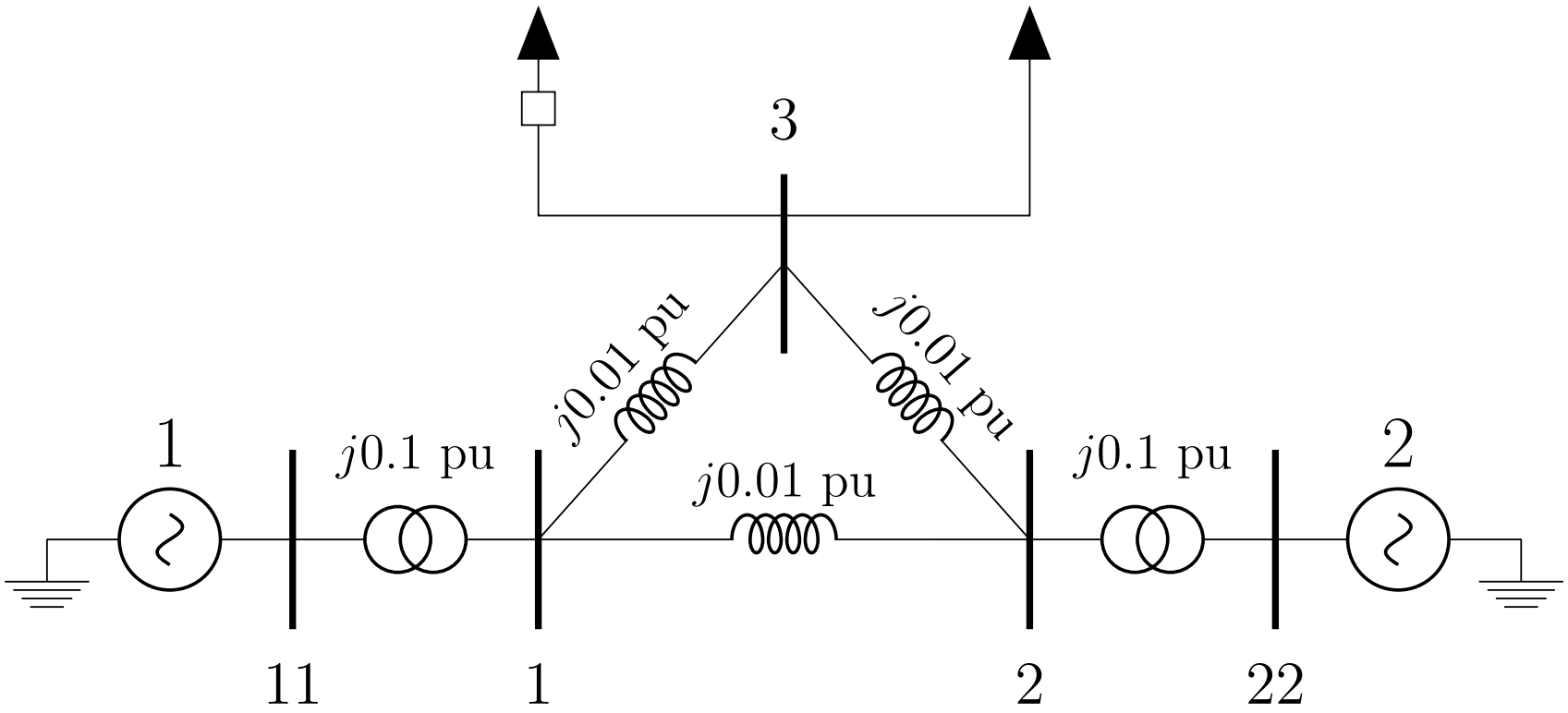
- PSLF communication
- Free
- Community Libraries
- Object Oriented Programming (Agent-Based Modeling)

- 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]

Coding decisions, approaches, and software operation.

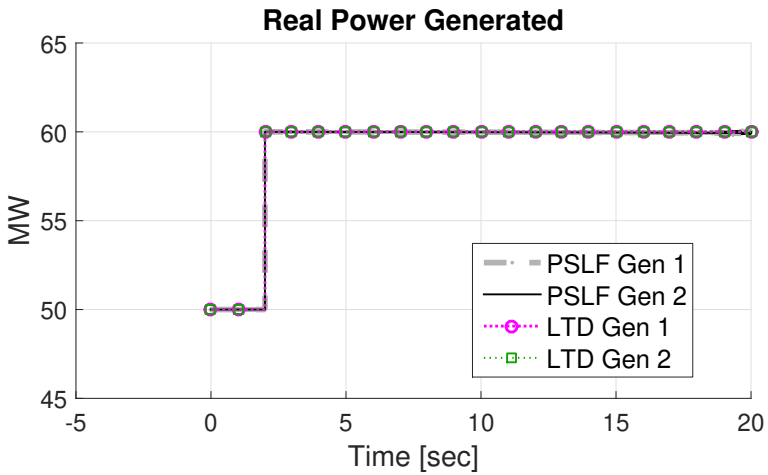


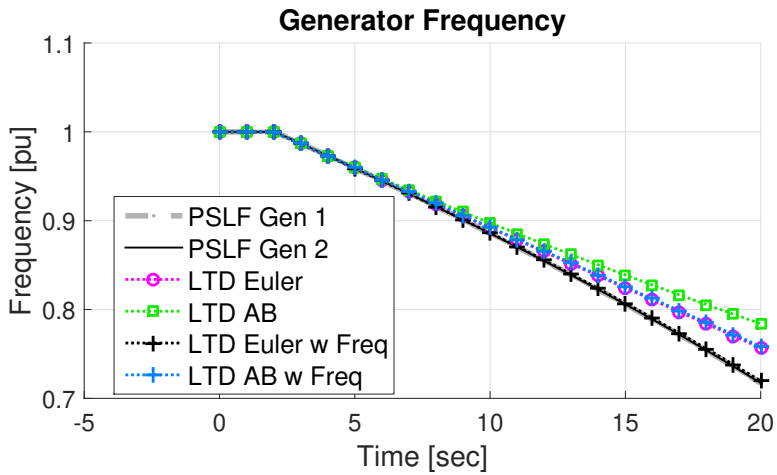
EE554.sav test system:

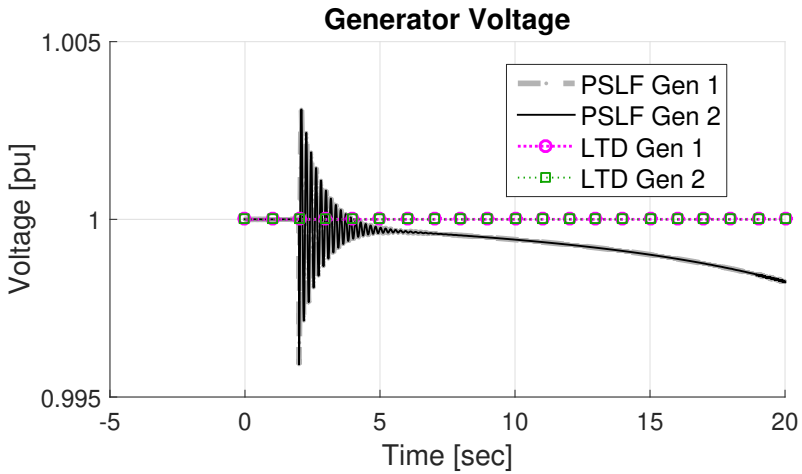


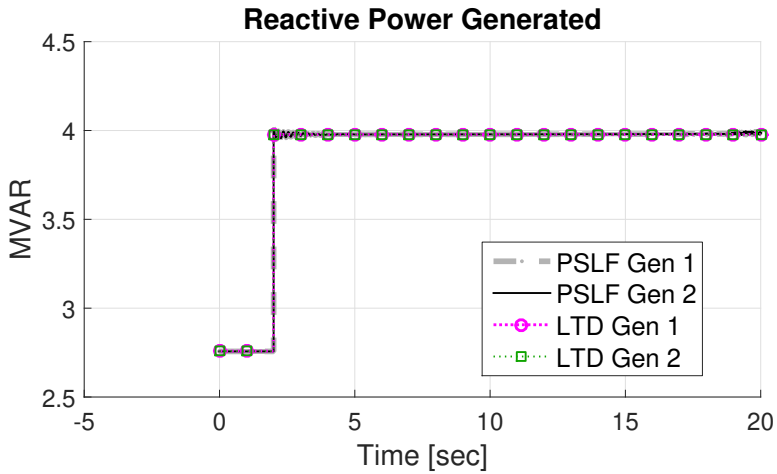
Generators are identical.
PSLF models have exciters.

System Response

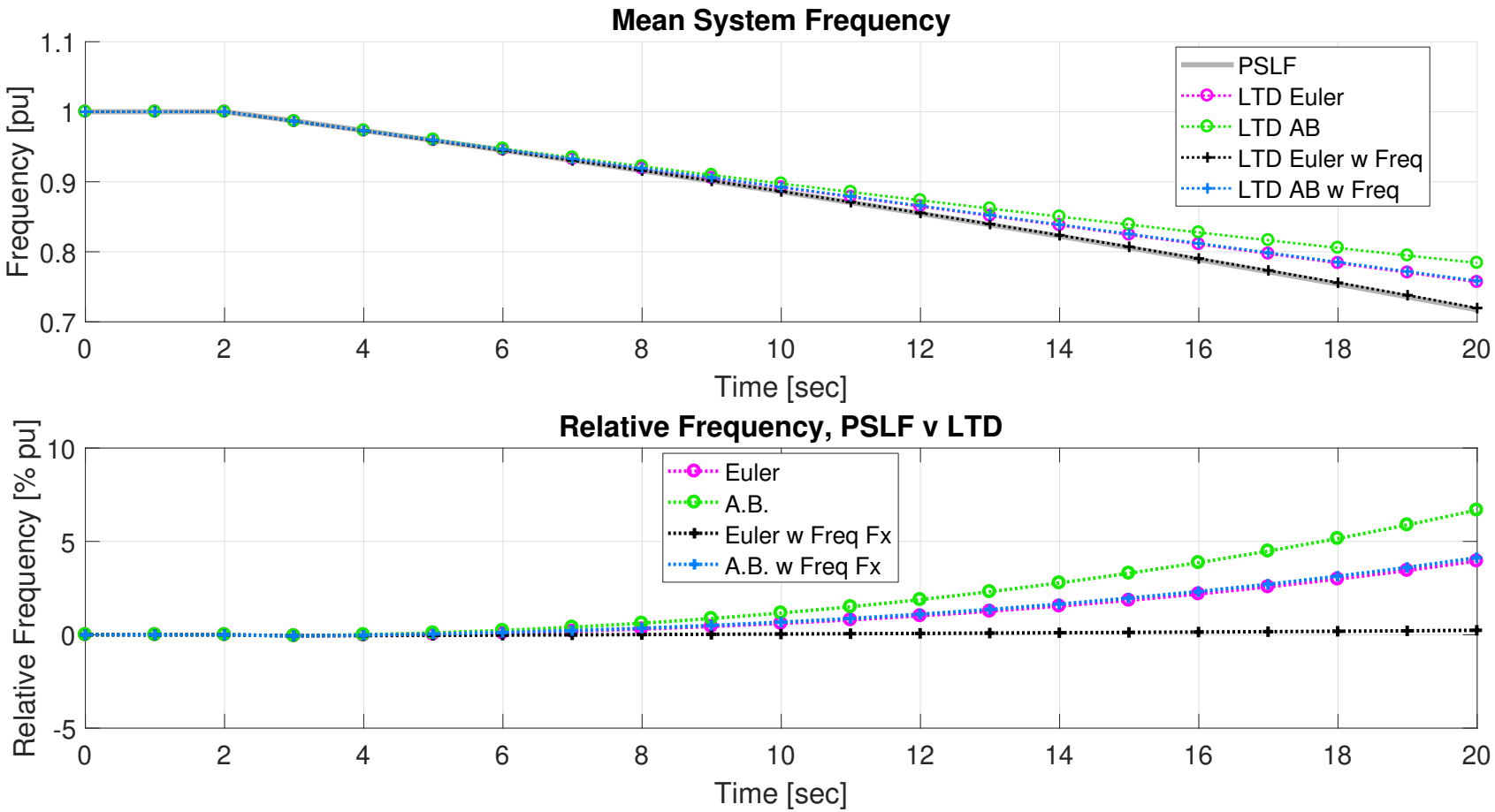




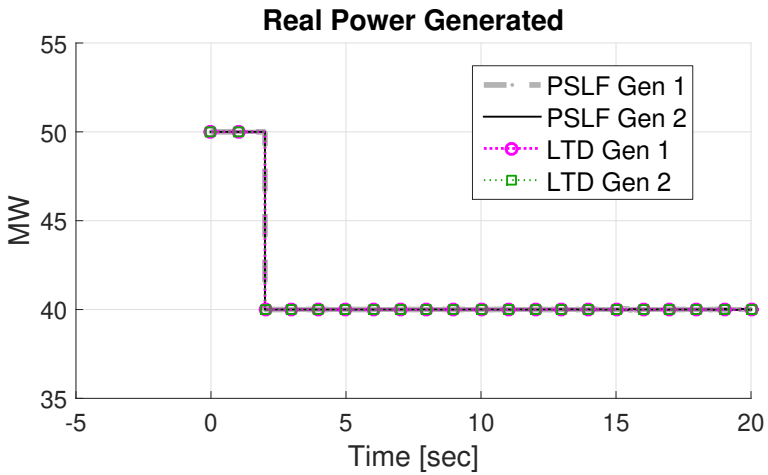


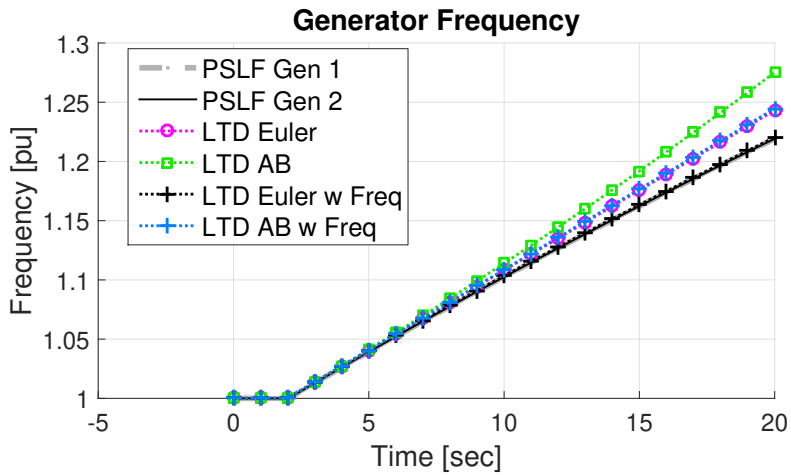


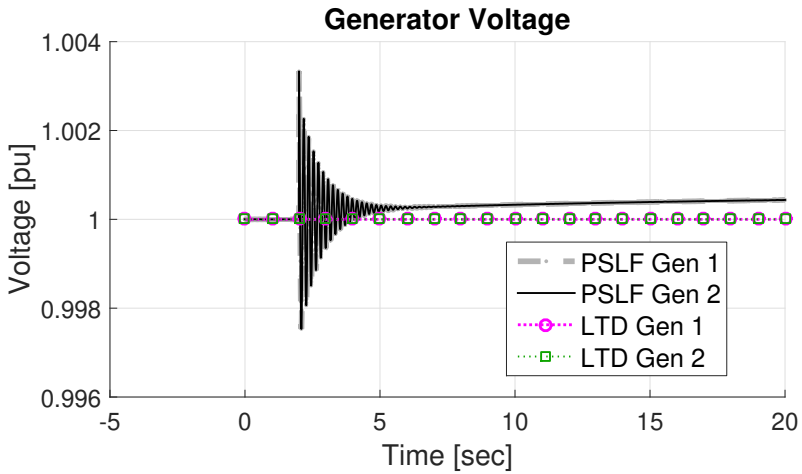
Detailed Frequency Response

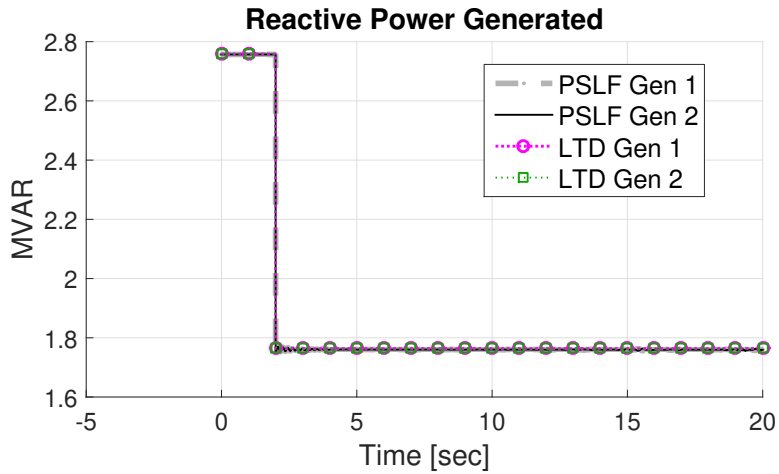


System Response









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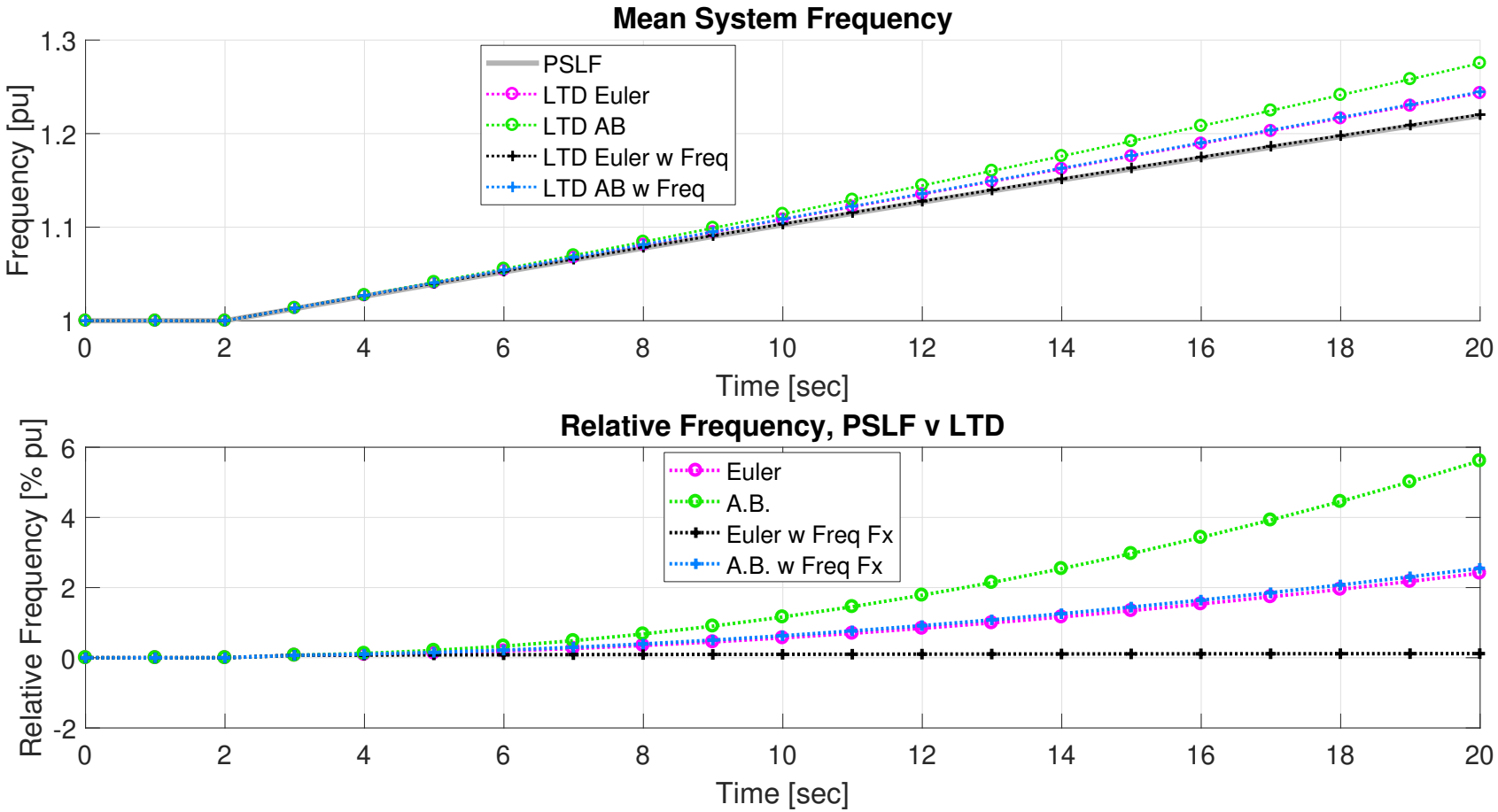
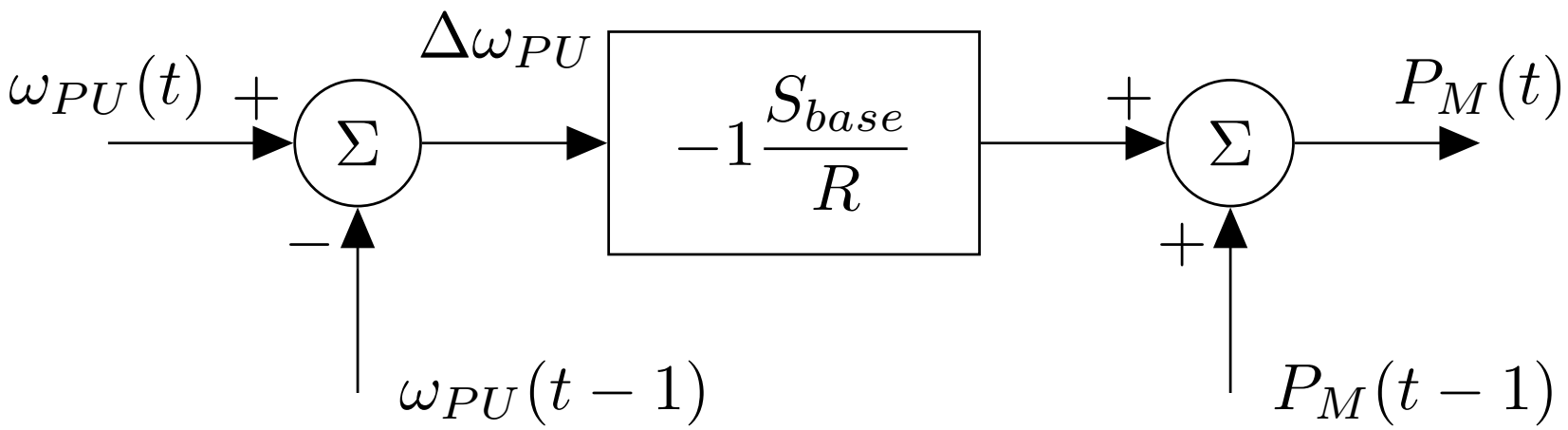


pgov1 : Proportional gain control of P_M

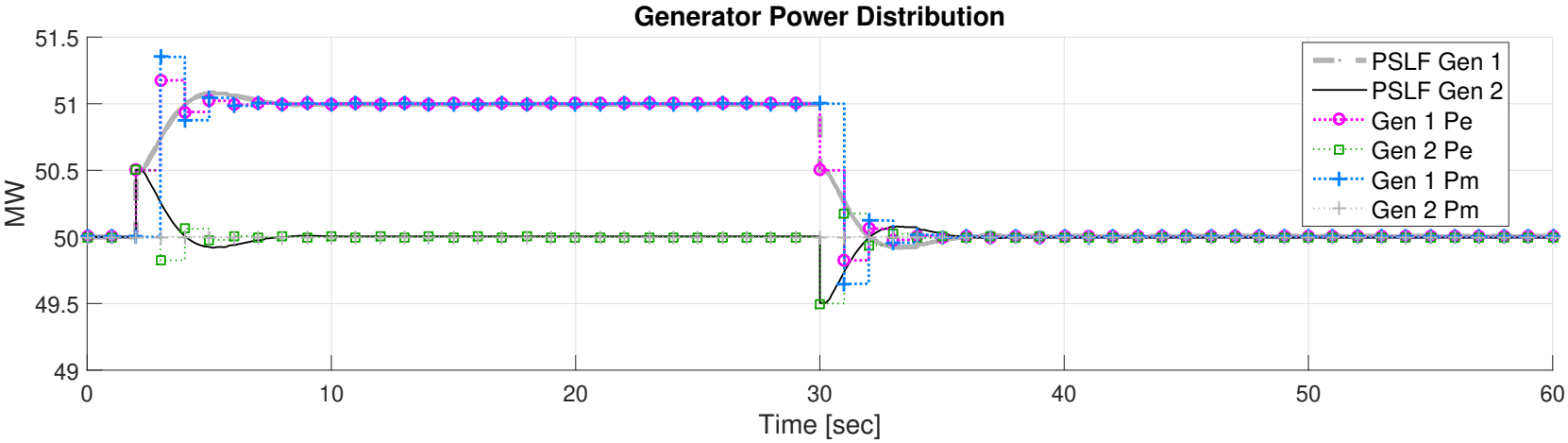


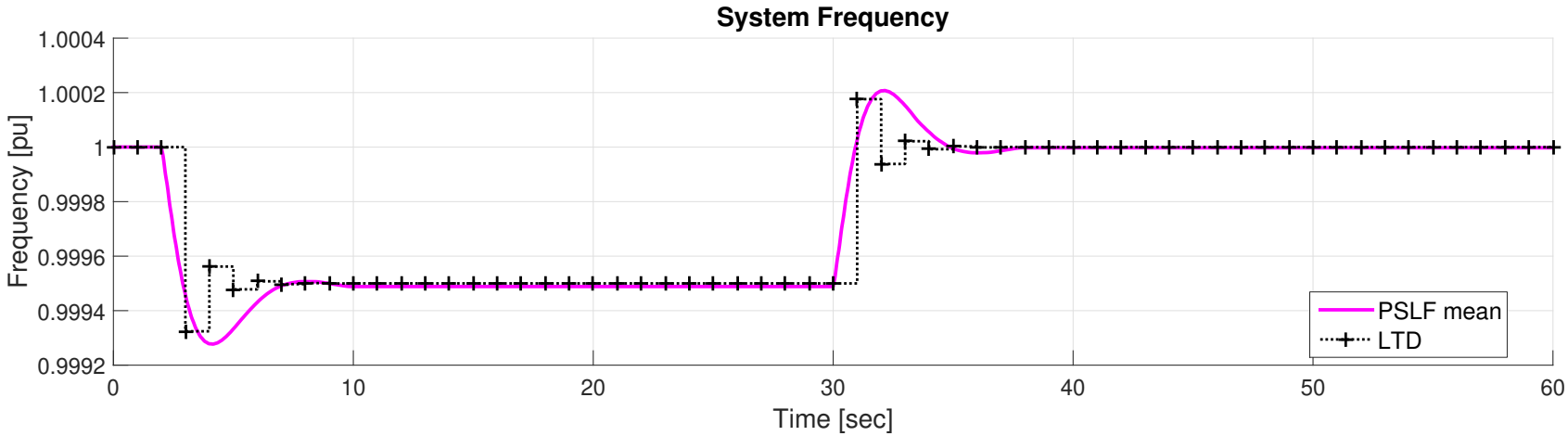
Entered into system via parsed text file:

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

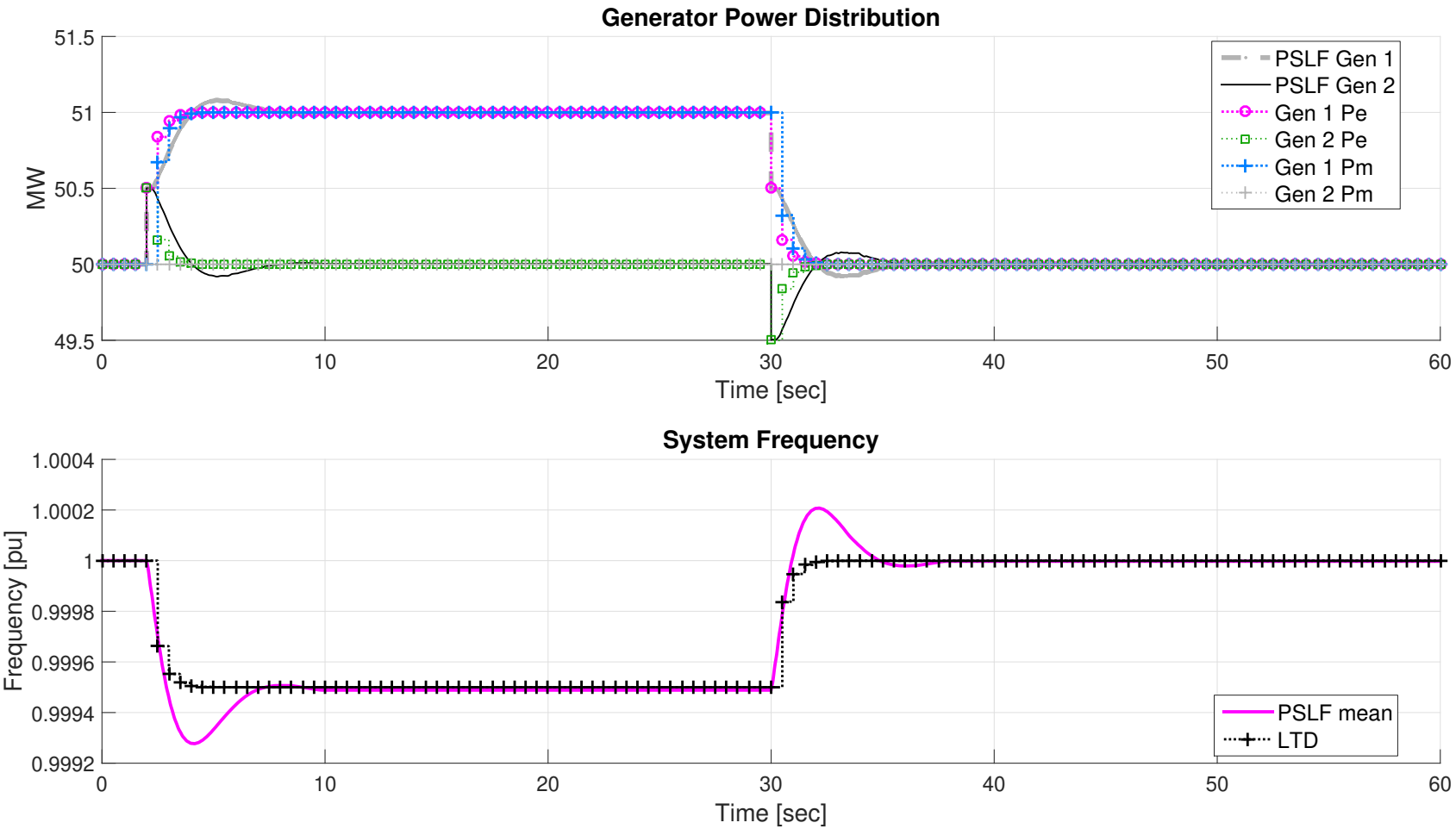
Model adapted from [3]

pgov1 on Gen 1, t_{step} =1 second

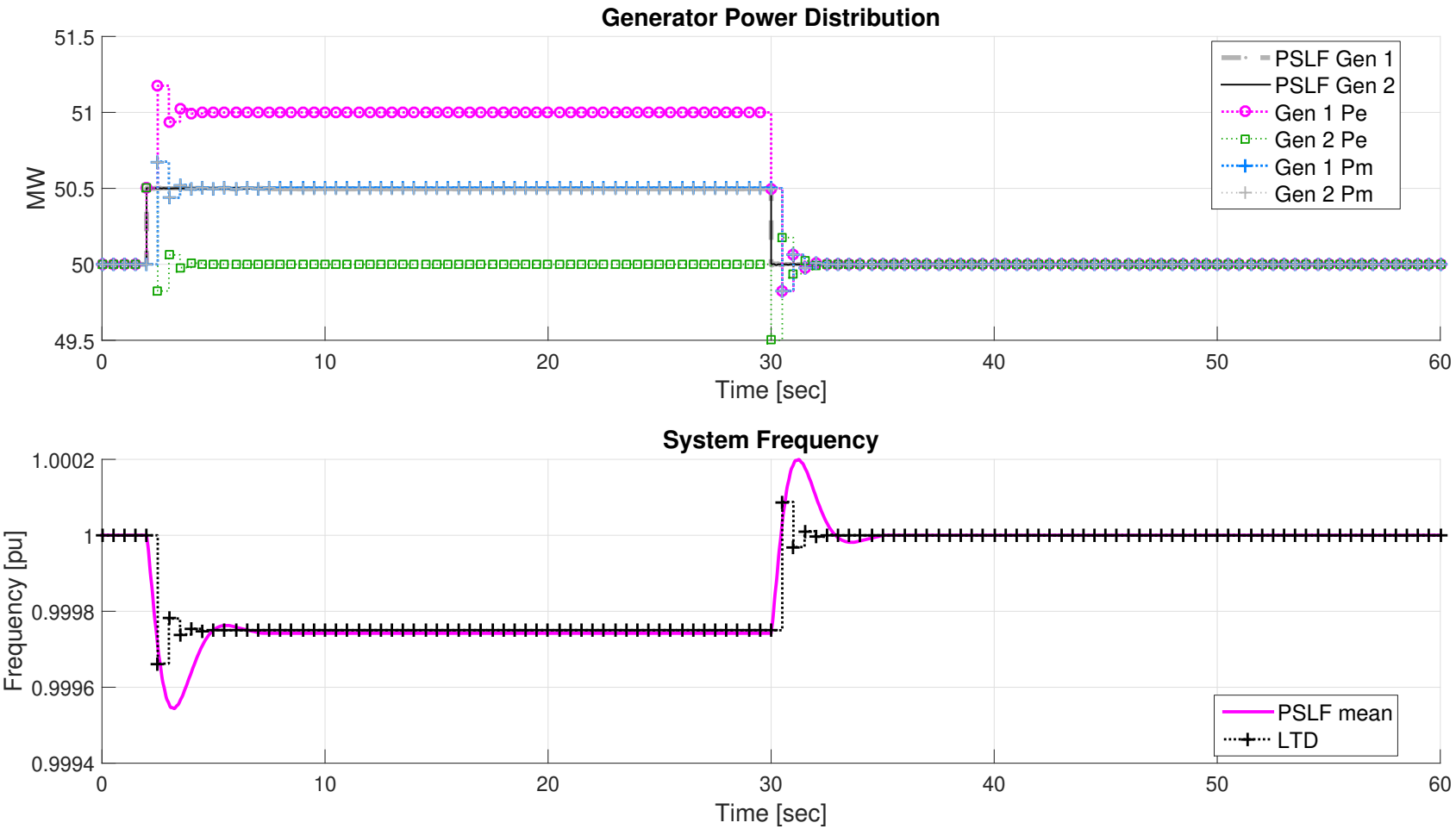




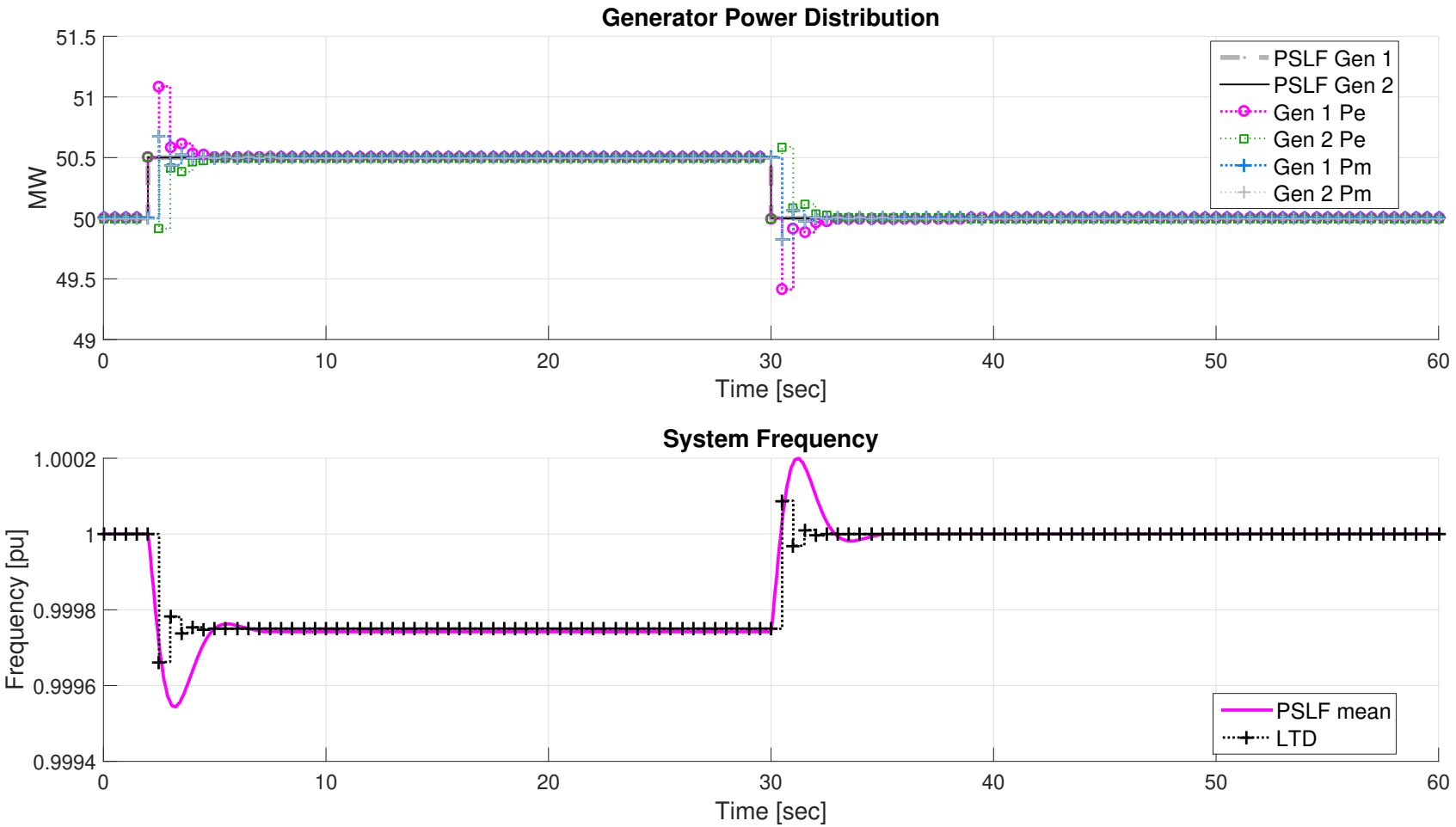
pgov1 on Gen 1, t_{step} =0.5 second



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

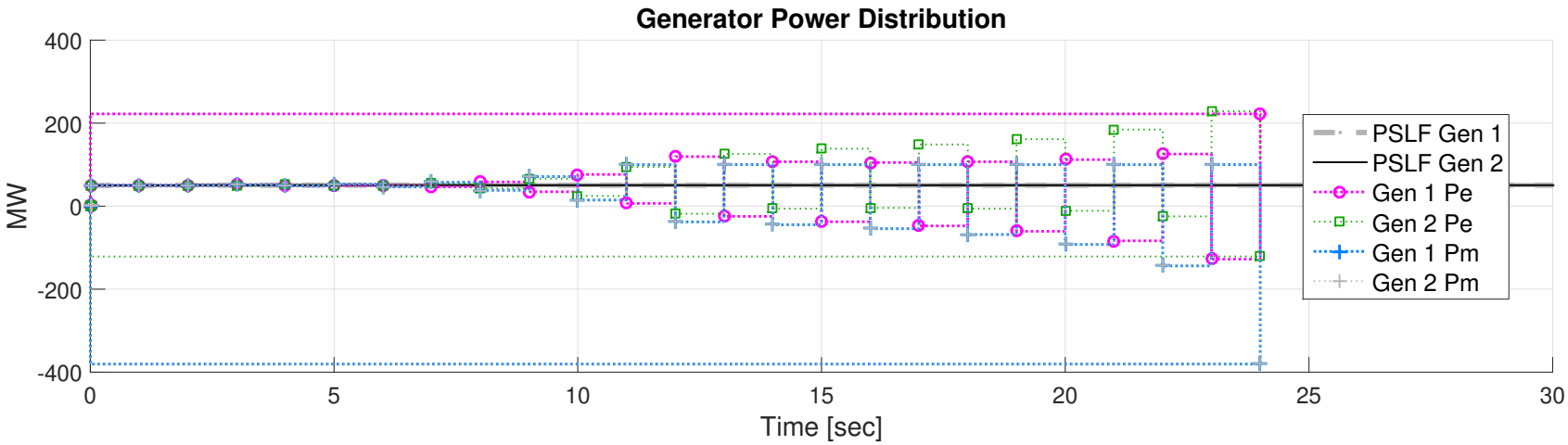


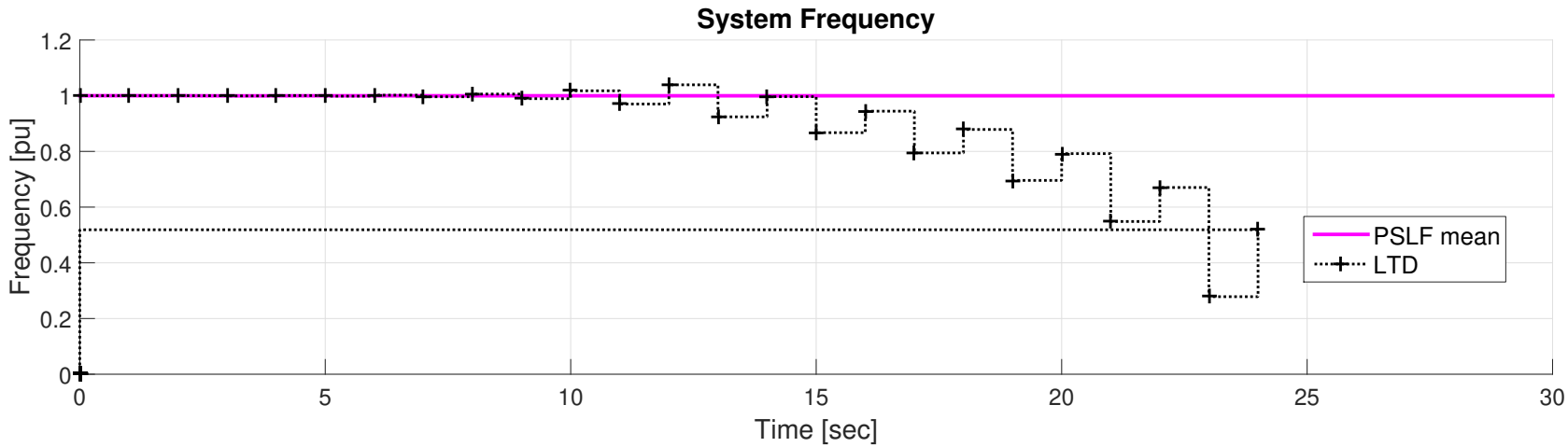
pgov1 on both Gens, t_{step} =0.5 sec., alt. P_e



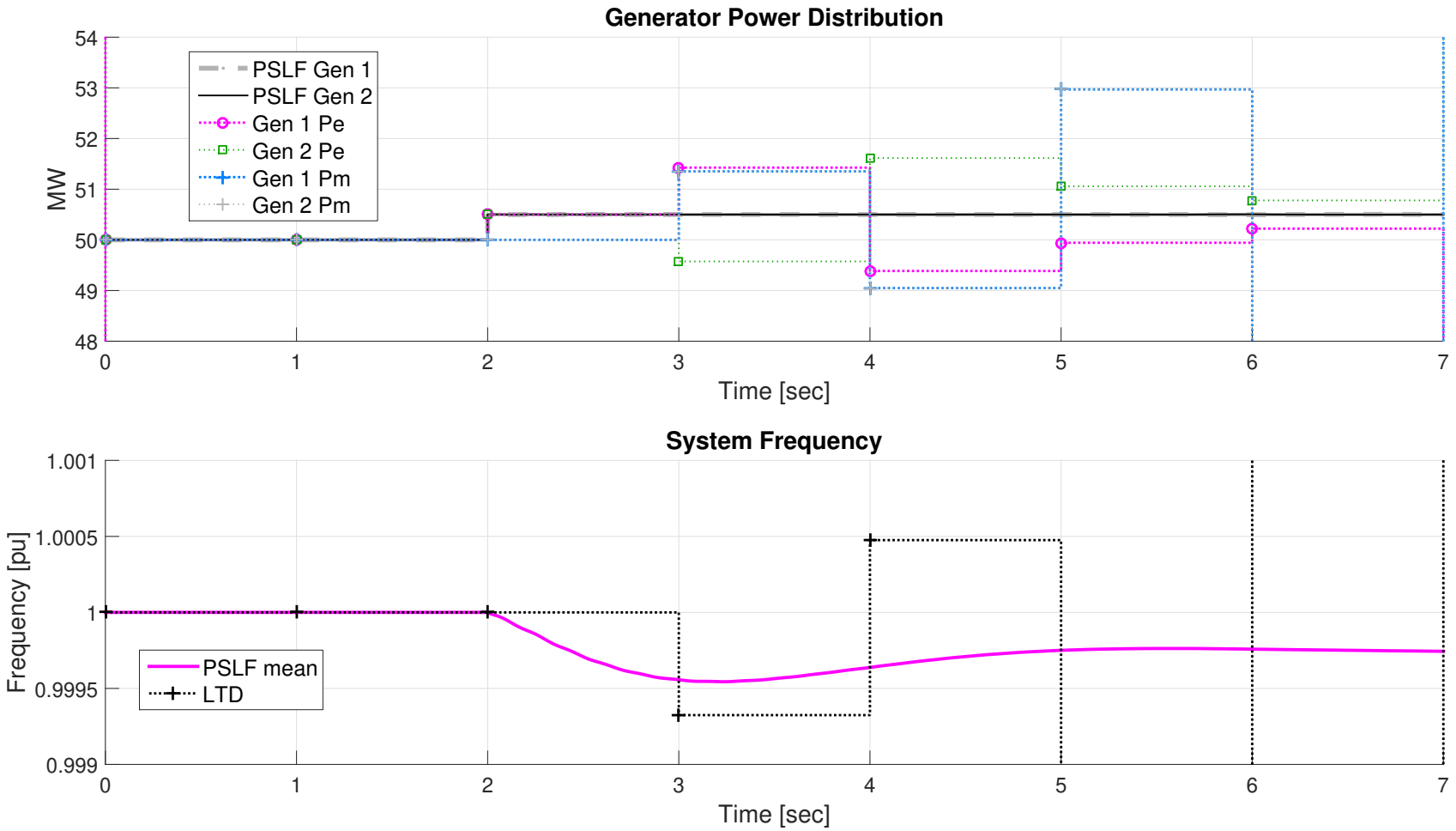
Dynamic model 'pgov1' experiment: +1 MW t=2, -1 MW t=30

pgov1 on both Gens, t_{step} =1 sec., alt. P_e





Detail, t_{step} =1 sec., alt. P_e



- 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=FVmQbfsOkGc

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