Effect of Governor Deadbands on Valve Travel using Long-Term Dynamic Simulation

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Abstract—The abstract goes here.

Index Terms—Governor deadbands, long-term dynamic simulation, time-sequenced power flow, valve travel

I. Introduction

Deadbands are commonly implemented in turbine speed governors to prevent a machine from responding to small frequency deviations that are ever present in electrical systems. Industry usage of deadbands is widely known, however, it is often overlooked in power system simulation. XXXrefKou2016 details how incorporating governor deadbands into transient simulation models can lead to results that better match measured power system events.

Additional intro thoughts:

deadband considered in transient stability time frame, not long-term,

possible real life benefits of improved deadbands

there doesn't seem to be a valve movement focused sim option...

Transient stability software is not meant to run for extended periods of time.

The resolution of data is orders of magnitude greater than is desired (ms v s).

II. Explanation of Simulation Technique

Time-sequenced power flow (TSPF) is a method for long-term dynamic (LTD) simulation proven to generate useful results [1]. The basic idea behind TSPF is to solve a power flow, perform system dynamics of interest, 're-seed' the power flow with new values, and repeat. A python based simulation software, Power System Long-Term Dynamic Simulator (PSLTDSim), has been developed to perform LTD simulations using TSPF. PSLTDSim has the ability to calculate system frequency, perform governor dynamics, model automatic generation control (AGC), and insert step, ramp, and noise perturbances into a power system.

A. Simulation Assumptions and Simplifications

Due to the relatively large time steps of 1 second involved with TSPF, numerous assumptions were made. Ideal exciters are assumed as modern exicters are typically fast enough to maintain reference voltage under stable conditions. Intermachine oscillations are ignored since subsynchronous resonances are sub-second and the time resolution used is not fine enough to capture these phenomena.

Simplifications of transient stability models are used in PSLTDSim. The only details required to model a generator are MW cap, MVA base, and machine inertia. Additionally, a deadband modified tgov1 governor model, Fig. 1, was created to model system governors.

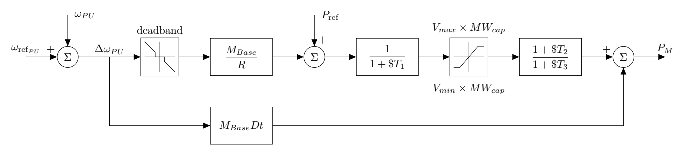

Fig. 1. Block diagram of modified tgvo1 model.

B. Combined System Frequency

Instead of frequency being calculated for each bus, a single combined swing equation is used to model only one combined system frequency. As shown in the per-unit (PU) equation (1), accelerating power from the entire system, as well as total system inertia $H_{PU,sys}$, is used to calculate $\dot{\omega}_{sys}$.

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

C. Distribution of Accelerating Power

In a system with N generators, total system accelerating power is calculated by

$$P_{acc,sys} = \sum_{i=1}^{N} P_{m,i} - \sum_{i=1}^{N} P_{e,i} \tag{2}$$

where $P_{m,i}$ is mechanical power and $P_{e,i}$ is electrical power of generator i.

The system accelerating power is then distributed to all generators in the system according to machine inertia as

$$P_{e,i} = P_{e,i} - P_{acc,sys}\left(\frac{H_i}{H_{sys}}\right) \tag{3}$$

where H is not PU and has units of $MW \cdot s$.

Once all accelerating power is distributed, the new value for each generators power output is used as initial conditions to solve a power flow. If the resulting power supplied by the slack generator is larger than the set slack tolerance, the difference is redistributed according to (3) until slack tolerance is met, or a maximum number of iterations take place.

III. Implementation of Deadbands

NERC suggestions for droop and deadband

A. Types of Deadbands

intentional vs unintentional None, step, no-step, non-linear droop. and equations for calculating

B. ERCOT Experience

Improved freq deviation (elimination of 'flat top' effect) 2012 creation of TRE-BAL-001...

IV. Simulation Validation

To validate the chosen simulation approach, identical system perturbances were performed in the GE Energy Positive Sequence Load Flow (PSLF) Dynamic Subsystem (PSDS) and PSLTDSim. Bus frequency and governed generator mechanical power data presented is from a 400 MW load step and 400 MW 40 second load ramp that start at simulation time 2. Mechanical power is compared as it is the closest available state to valve travel recorded in PSDS.

To compare frequency data from PSDS to LTD, a single weighted frequency based on generator inertia was calcualted using (4).

$$f_w = \sum_{i=1}^{N} f_i \frac{H_{PU,i} M_{base,i}}{H_{sys}} \tag{4}$$

$$\text{where } H_{sys} = \sum_{i=1}^{N} H_{PU,i} M_{base,i} \tag{5}$$

Due to the different time steps, when calculating the difference between PSDS and LTD, multiple PSDS values have the same held LTD value subtracted from them. For instance, any PSDS(t = 3.x) would have the LTD(t = 3) value subtracted from it for comparison.

A. The MiniWECC System

The power system used for validation and valve travel experiments, the miniWECC shown in Fig. 2, is a 120 bus 34 generator system created in PSLF. All governors in the miniWECC are modeled with the tgov1 which enabled easier validation. Further details about the creation and use of the miniWECC may be found in ...

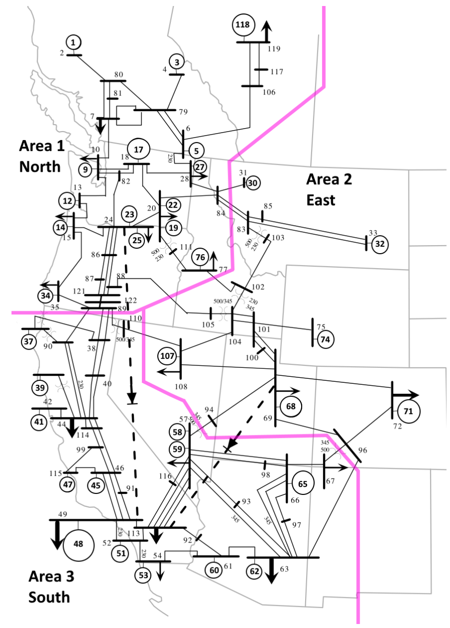

Fig. 2. MiniWECC System.

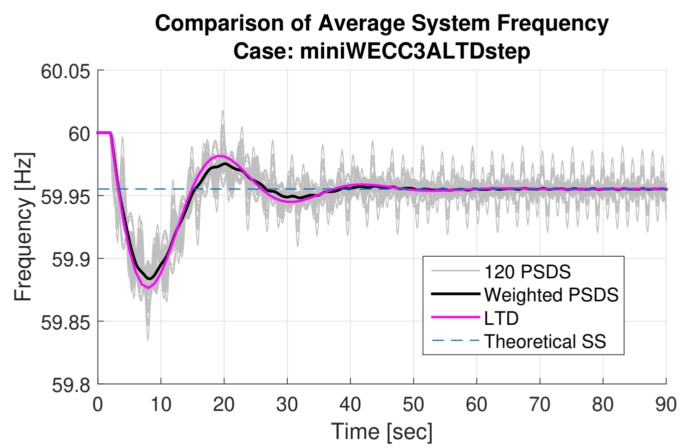

Fig. 3. Comparison of frequency during load step.

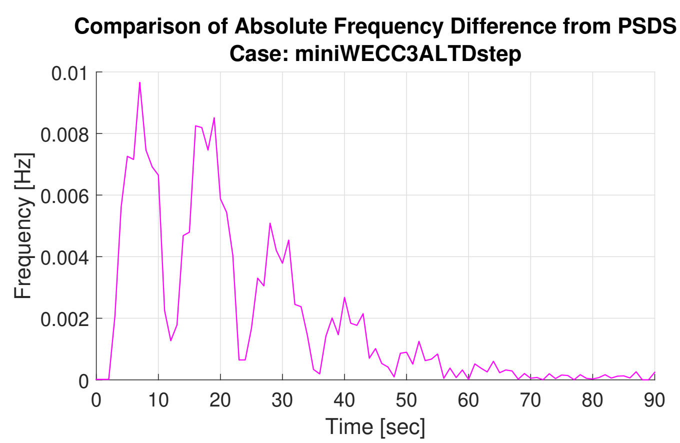

Fig. 4. Absolute difference of weighted frequency during load step.

1) Load Step Results: As shown in Fig. 3, all individual PSDS frequencies begin to oscillate after the perturbance while the weighted PSDS frequency appears to follow the general center of oscillation. The LTD system frequency is less oscillatory than the weighted frequency with only minor differences between the two. Fig. 8 quantifies these differences.

When comparing mechanical power output in Fig. 5, large MW differences can be seen, however, the percent difference data in Fig. 6 shows results less than 5% max difference, and an average percent difference of less than ≈0.5%.

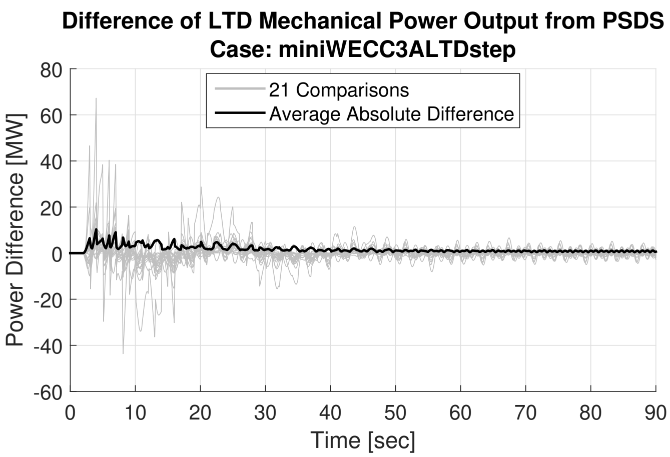

Fig. 5. Comparison of mechanical power output during load step.

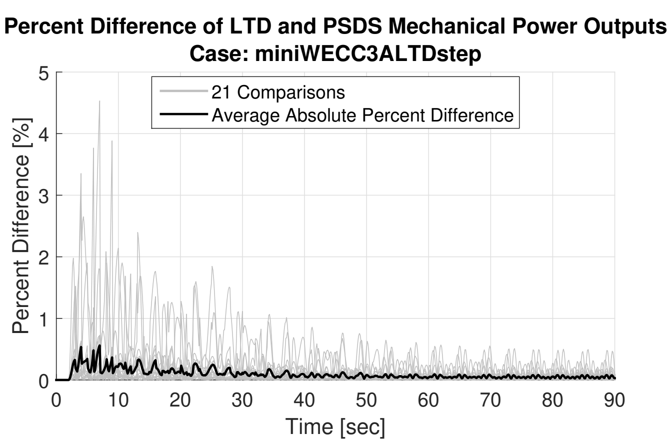

Fig. 6. Percent difference of mechanical power output during load step.

2) Load Ramp Results: Ramp perturbance results, in Fig. 7-9 show frequency of LTD being within 1.2 mHz of PSDS and mechanical power differences of less than ±10 MW or 1% difference max (0.2% average).

V. Case Study

Explanation of simulations to do...

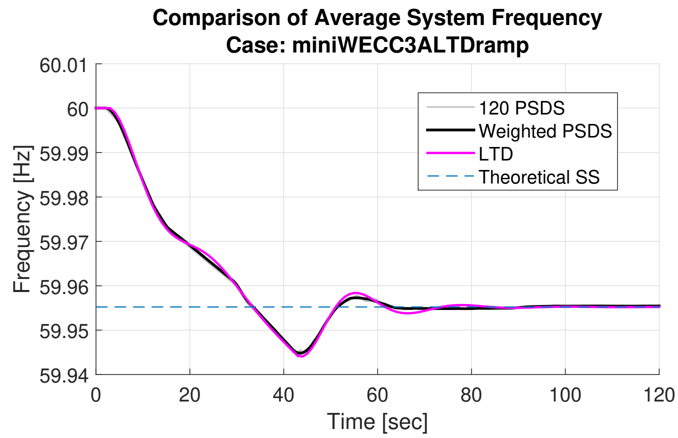

Fig. 7. Comparison of frequency during load ramp.

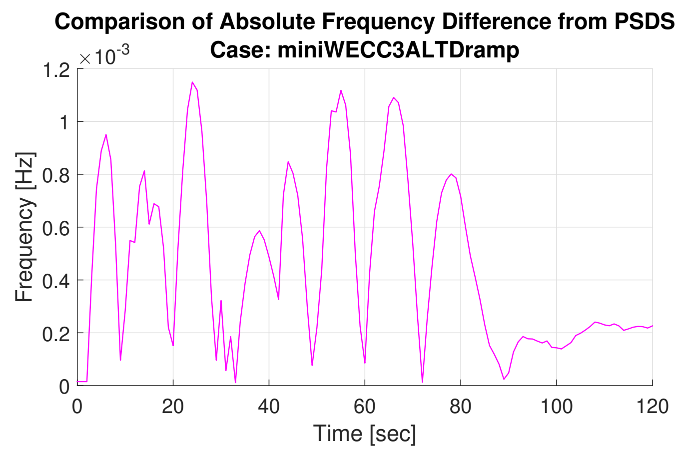

Fig. 8. Absolute difference of weighted frequency during load ramp.

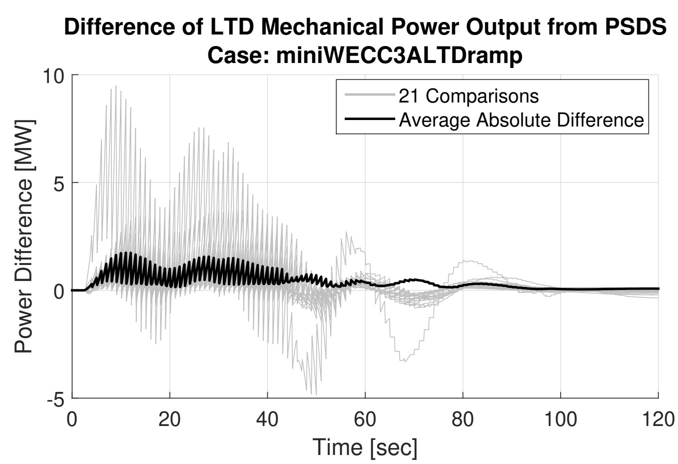

Fig. 9. Comparison of mechanical power output during load ramp.

30 minutes of noise with various deadbands and resulting valve travel. Cases of intterest: No deadband, step deadband, no-step deadband, nl-droop deadband.

Universal acceptance sim: At least 1 area with a step deadband, others with linear or no deadband. Should show

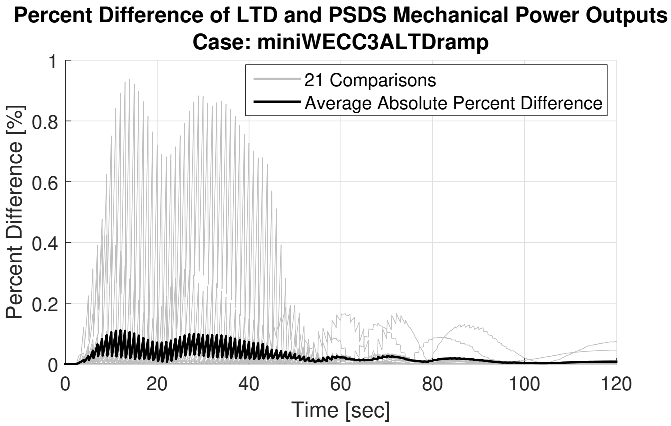

Fig. 10. Percent difference of mechanical power output during load ramp.

unequal distribution of valve travel.

A. System Modifications

The system was modified to include three areas for AGC simulation. PSLTDSim was used to set all area governor deadbands to 5%. Governors were removed from some units so that only ≈ 20% of generation capacity in each area has governor control. A generic AGC routine that filters area control error (ACE) through a proportional-intergal (PI) controller was added to each area. AGC messages are sent select generation units with governors every 15 seconds.

B. Simulation Results

To verify desirable AGC control operation, a simple 1500 MW generation loss event was simulated.

Noise tests, valve travel movement, table inputs, etc.

VI. Conclusion

Maybe having deadbands is a bad move - an extra work caused by procrastination type of situation. But everyone probably needs to be on board, otherwise some may ride free while others unfairly pick up the slack.

Acknowledgment

The authors would like to thank...

References

[1] E. Heredia, D. Dosterev, and M. Donnelly, "Wind hub reactive resource coordination and voltage control study by sequence power flow," IEEE, 2013.

[2] P. Kundur, Power System Stability and Control. McGraw-Hill, 1994.

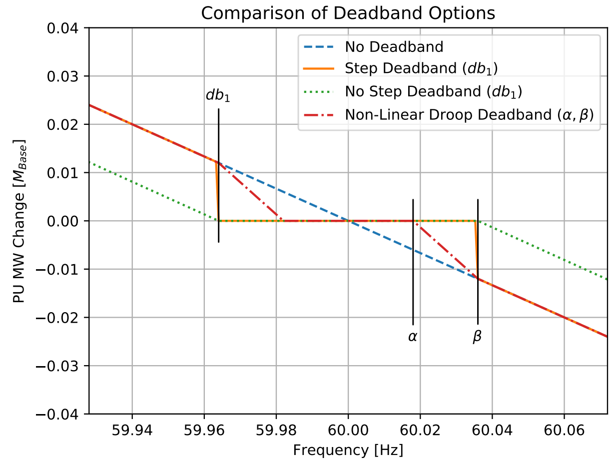

Fig. 11. Testing of figure format.

VII. Non-Text Format Templates

This section meant to provide template figures, tables, equations, and references that can be copied and pasted to other parts of the document in a simple manner.

Figures will behave as Fig. 11. Note that the placement may seem random, but is chosen by LaTeX automatically.

The default IEEE table example leaves something to be desired that is fulfilled by using the booktabs package. This is shown in Table I.

TABLE I
Generic governor model parameters.

Parameter	Steam	Hydro	Gas
Ts	0.04	0.40	0.50
Tc	0.20	45.00	10.00
T3	0.00	5.00	4.00
T4	1.50	−1.00	0.00
T5	5.00	0.50	1.00

Equations are entered as one may normally do in a LaTeX situation and referenced as (6) and (7).

$$f_{ss} = f_{ref} + \Delta f = f_{ref} + \frac{\Delta P}{S_{Base}\beta} \tag{6}$$

$$\beta = \sum_{i=1}^{N} \frac{1}{R_i \frac{S_{Base}}{M_{Base,i}}} \tag{7}$$

References are only included if cited. For instance [2] or [1] are randomly cited. Note that the sorting order is set to none, which lists references in order cited.