***Abstract*—This paper investigates the impact of governor deadbands on valve travel using a novel long-term dynamic (LTD) simulation software environment. The Python based LTD software utilizes a commercial power-flow solver to execute a sequence of power flows that is shown to capture long-term power system dynamics with acceptable accuracy. While classical transient stability simulation (CTSS) is sufficient for investigating the impact of governor deadbands on primary frequency response, LTD software is needed for analyzing the impact of governor deadbands on fuel valve travel over longer periods of time. The presented LTD software enables simulations from tens of minutes to hours on full system base cases. Cumulative valve travel is proposed as a metric for evaluating the impact of various deadband settings. It is shown that use of specific governor deadbands can actually increase cumulative valve travel over what would be expected without a deadband.**

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

I. Implementation of Deadbands

FERC Order 842 specifies a droop of 5% and governor deadbands of a maximum 36 mHz[1]. In practice, several types of deadbands are currently used as physical control implementation is left to generator operators.

A. Types of Deadbands

Fig. 1 presents implementations of deadbands that meet FERC specifications. If a governor has no deadband, a change in output power is requested for any frequency deviation. A step deadband ignores any frequency smaller than the setpoint $\pm db_1$ and then steps to meet the set droop curve. A no-step deadband pushes the original droop curve away from the nominal frequency allowing for the droop curve to cross zero at $\pm db_2$ but never returns to the step or no deadband droop curve. A non-linear deadband is introduced that linearly increases from $\pm\alpha$ to $\pm\beta$, after which it follows the original droop curve.

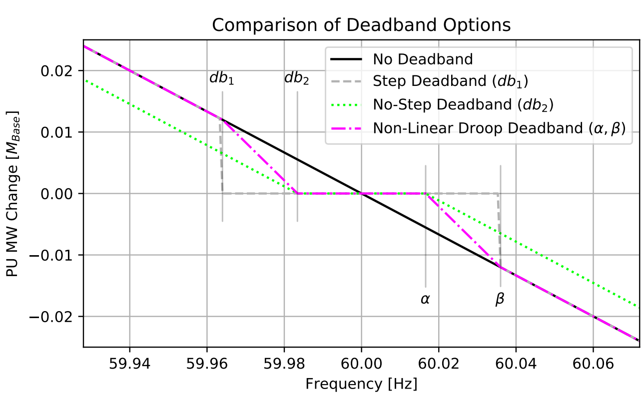

Fig. 1. Different types of deadbands.

II. Initial Results

To assess long-term impacts of governor deadbands, thirty minutes of random load noise was applied to the miniWECC. All governors had identical deadband settings and PSLTDSim was used to set all governor droops to 5%. Some governors were removed from the system so that only ≈20% of generation capacity in each area had governor control. Each type of deadband shown in Fig. 1 was simulated.

Another experiment was conducted to explore a non-homogeneous deadband scenario where all deadbands were the same type, but some had different mHz deadbands. Although PSLTDSim can model AGC, it was not enabled for any presented simulation.

A. System Noise Injection

At every time step, noise is injected into each load $P_{L,i}$ in the system according to

$$P_{L,i} = P_{L,i}(1 \pm N_Z Rand_i) \tag{1}$$

where N_Z represents the maximum amount of random noise to inject as a percent, and $Rand_i$ is a randomly generated number between 0 and 1 inclusive. The decision to add or subtract noise is chosen by another randomly generated number. As described in [2], (1) creates random walk behavior in load that is representative of real power systems.

B. Noise Simulation Results

N_Z was set to 0.03 for all simulations. The change in system loading caused by the noise is shown in Fig. 2. Fig. 3 shows the resulting system frequency for each type of deadband. The step deadband holds frequency almost exactly on the set deadband except when system loading decreases during minutes 7-11. The other deadband options maintain system frequency near their respective mHz setting until loading increases beyond a point near minute 17.

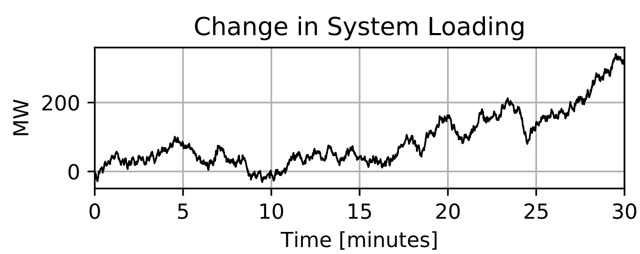

Fig. 2. Change in total system loading.

Table I summarizes the valve travel for each generator in the system over the entire 30 minute simulation. A step type deadband has the largest total travel while the no-step deadband has the least.

The first three minutes of a single generators valve travel are shown in Fig. 4 to compare how different deadbands affect valve movement.

A step deadband will send pulse train-esq control signals to the governor valve when system frequency is oscillating over the deadband. These repeated control pulses greatly increase valve travel over the more linear deadband options.

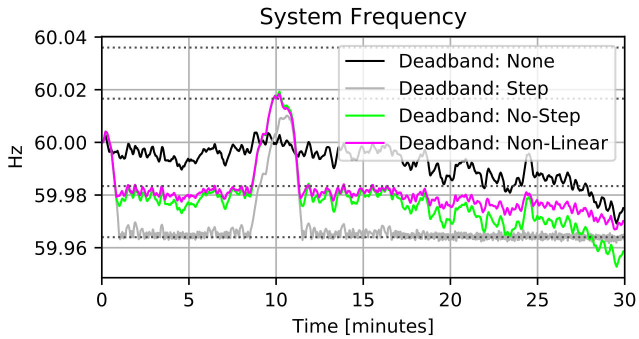

Fig. 3. System frequency response of various deadband scenarios.

TABLE I
TOTAL VALVE TRAVEL FOR VARIOUS DEADBAND SCENARIOS.

Generator	No DB	Step	No-Step	N-L Droop	No-Step Non-H
	Valve Travel [PU]				
17	0.16	7.48	0.15	0.23	0.19
23	0.16	7.48	0.15	0.23	0.19
30	0.16	7.48	0.15	0.23	0.19
32	0.16	7.54	0.15	0.23	0.19
107	0.16	7.54	0.15	0.23	0.19
41	0.15	6.44	0.14	0.23	0.06
45	0.15	6.44	0.14	0.23	0.06
53	0.16	7.54	0.15	0.23	0.06
59	0.15	6.44	0.14	0.23	0.06
Total:	1.41	64.38	1.32	2.07	1.19

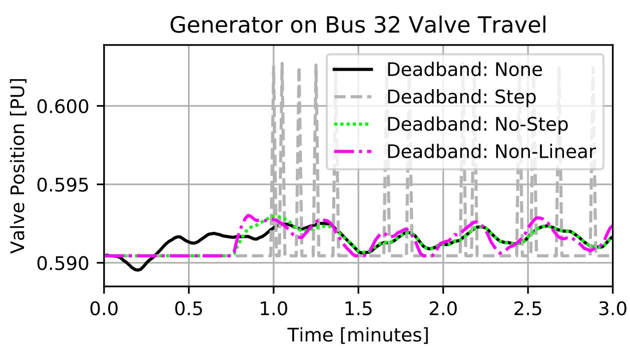

Fig. 4. Valve movement deadband comparisons.

C. Non-Homogeneous Deadband Simulation Results

With all governors using a no-step type deadband, two of the three areas mHz deadband was to 16.6 mHz while the third was set to 36 mHz. The resulting system frequency is shown in Fig. 5. Individual valve travel for each generator is shown in Table I under the 'No-Step Non-H' column, and Fig. 6 shows the average valve travel over time for each area.

As expected, governors with a larger deadband won't respond until after frequency drops below their deadband while governors with smaller deadbands work to maintain frequency. In this case, the governor valves with a smaller deadband move three times more than those with a larger deadband even though total system valve movement is reduced from the homogeneous no-step scenario.

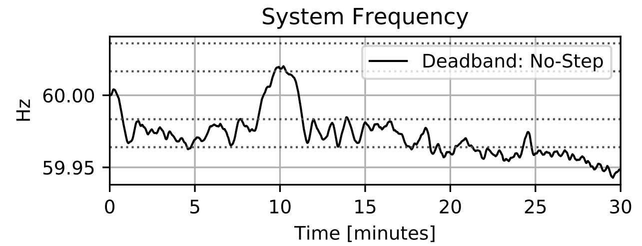

Fig. 5. System frequency response to 0.03% load noise where no-step deadbands have different settings.

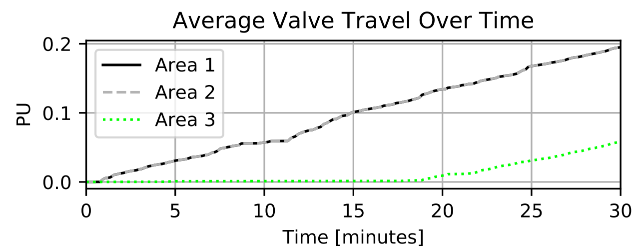

Fig. 6. Average valve travel by area for non-homogeneous deadband test.

III. CONCLUSION

This work demonstrates that deadband configurations play a large role in dictating valve travel. Counterintuitively, a step deadband can lead to vastly increased valve travel compared to other deadband options. Smaller deadbands can reduce valve travel if adopted interconnection-wide, but in a system with various deadband settings, machines with smaller deadbands will respond more than machines with larger deadbands.

Further, this work demonstrates the need for a simulation environment that can capture long-term power system dynamics with appropriate static and dynamic models. The TSPF approach to LTD simulation that PSLTDSim utilizes is shown be be most useful. Future work in this area will focus on using the cumulative valve travel metric to study and optimize various governor and AGC control strategies.

REFERENCES

[1] FERC, "Essential reliability services and the evolving bulk-power system–primary frequency response," Federal Energy Regulatory Commission, Docket No. RM16-6-000 Order No. 842, Feb. 2018.

[2] C. W. Taylor and R. L. Cresap, "Real-time power system simulation for automatic generation control," IEEE Transactions on Power Apparatus and Systems, 1976.