A Generalized PSS Architecture for Balancing Transient and Small-Signal Response

Ryan T. Elliott , Payman Arabshahi , and Daniel S. Kirschen

IEEE Transactions on Power Systems, Vol.35, No. 2, pp.1446-1456, March 2020

Athul Jose P

11867566

Reference Paper

1446 IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 35, NO. 2, MARCH 2020

A Generalized PSS Architecture for Balancing Transient and Small-Signal Response

Ryan T. Elliott, *Student Member, IEEE*, Payman Arabshahi, *Senior Member, IEEE*, and Daniel S. Kirschen, *Fellow, IEEE*

***Abstract*—For decades, power system stabilizers paired with high initial response automatic voltage regulators have served as an effective means of meeting sometimes conflicting system stability requirements. Driven primarily by increases in power**

Correspondingly, the rapid growth of power electronic loads may make the system load stiffer with respect to changes in voltage [5], [6]. In parallel with these changes, wide-area

Introduction

- Exponential increase in renewable penetration
- Increase in inverter based systems
- Reduced system inertia and damping
- Increase in voltage oscillations
- Small signal and transient stability issues

- System load is becoming stiffer with respect to change in voltage
- Advancements in wide area monitoring systems for control purposes

R. T. Elliott, P. Arabshahi, and D. S. Kirschen, ‘‘A generalized PSS architecture for balancing transient and small-signal response,’’ IEEE Trans. Power Syst., vol. 35, no. 2, pp. 1446–1456, Mar. 2020.

Motivation

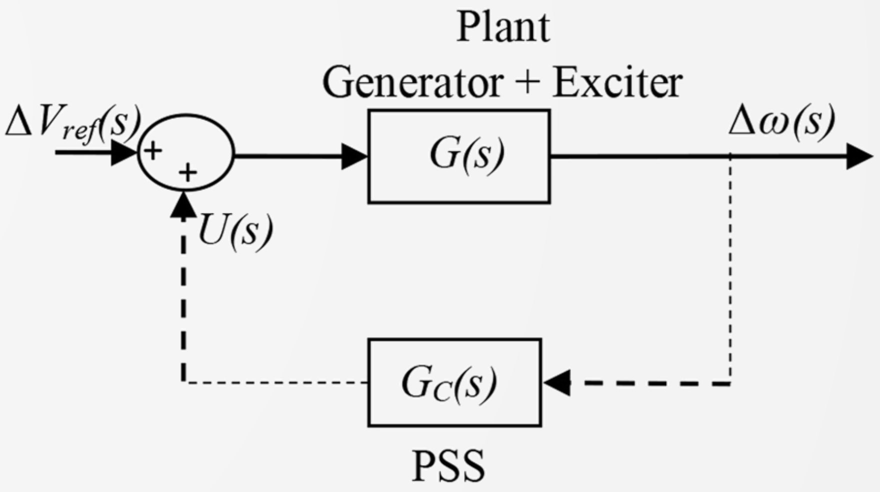
Renewable Energy Integration: Increasing reliance on renewable sources replaces conventional generation, impacting grid inertia, voltage support, and oscillation damping, leading to low-frequency oscillations.

Wide-Area Monitoring Systems (WAMS): Utilizing Phasor Measurement Units (PMUs) within advanced WAMS offers real-time data on grid conditions over large regions, enhancing control strategies and situational awareness to counter stability challenges.

Power System Stabilizers (PSS) and AVR Collaboration: PSS, in coordination with Automatic Voltage Regulators (AVR), improves transient stability

Power System Stabilizer

- Synchronous generators have high gain AVRs to enhance stability margins.
- High gain AVR increases synchronizing torque, however, they reduces the damping torque.
- PSS produce auxiliary signals to excitation systems to reduce low frequency oscillation
- Design of PSS is generally done based on fixed operating condition.



https://pcmp.springeropen.com/articles/10.1186/s41601-020-00165-9/figures/3

Control Strategy

Swing equation

$$\dot{\omega}(t) = -\frac{D}{2H}\left[\omega(t) - \omega_0\right] + \frac{1}{2H\omega(t)}\left[P_m(t) - P_e(t)\right]$$

Linearizing about a non equilibrium trajectory

$$\Delta\dot{\omega}(t) = -\left[\frac{D}{2H} + \frac{\overline{P}_m(t) - \overline{P}_e(t)}{2H\overline{\omega}(t)^2}\right]\Delta\omega(t) + \frac{1}{2H\overline{\omega}(t)}\left[\Delta P_m(t) - \Delta P_e(t)\right]$$

$$\Delta\dot{\omega}(t) = -\frac{\mathfrak{D}(t)}{2H}\Delta\omega(t) + \frac{1}{2H\overline{\omega}(t)}\left[\Delta P_m(t) - \Delta P_e(t)\right]$$

$$\mathfrak{D}(t) = D + \frac{\overline{P}_m(t) - \overline{P}_e(t)}{\overline{\omega}(t)^2}$$

$$\Delta\omega(t) = \omega(t) - \overline{\omega}(t)$$

function of time tracks changes in overall system operating point

R. T. Elliott, P. Arabshahi, and D. S. Kirschen, ‘‘A generalized PSS architecture for balancing transient and small-signal response,’’ IEEE Trans. Power Syst., vol. 35, no. 2, pp. 1446–1456, Mar. 2020.

Center of Inertia Speed

COI speed is the common synchronous speed to which generators tend in steady-state conditions

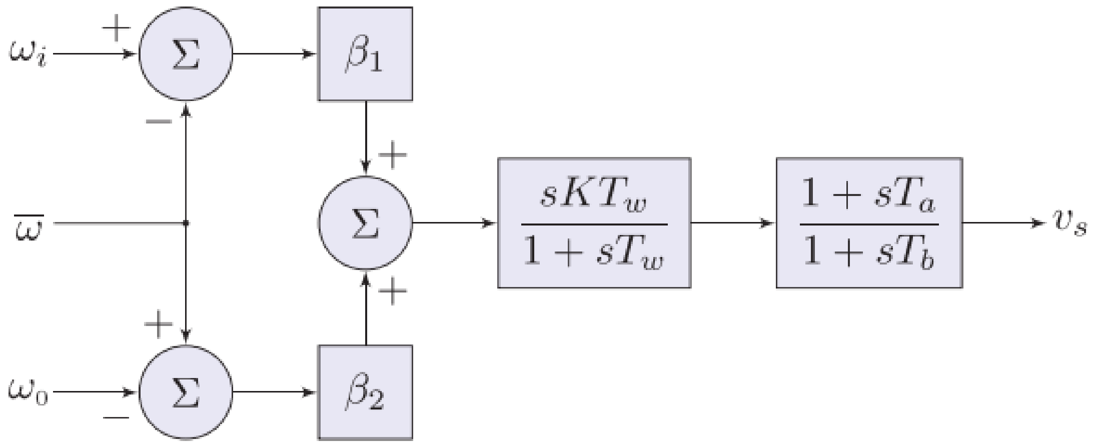
$$\overline{\omega}(t) \approx \frac{\sum_{i \in \mathcal{I}} H_i \omega_i(t)}{\sum_{i \in \mathcal{I}} H_i}$$

COI speed calculation using weighted average of frequency measurements

$$\overline{\omega}(t) = \frac{1}{f_0} \sum_{k \in \mathcal{K}} \alpha_k f_k(t)$$

R. T. Elliott, P. Arabshahi, and D. S. Kirschen, ''A generalized PSS architecture for balancing transient and small-signal response,'' IEEE Trans. Power Syst., vol. 35, no. 2, pp. 1446–1456, Mar. 2020.

Δω-Type PSS



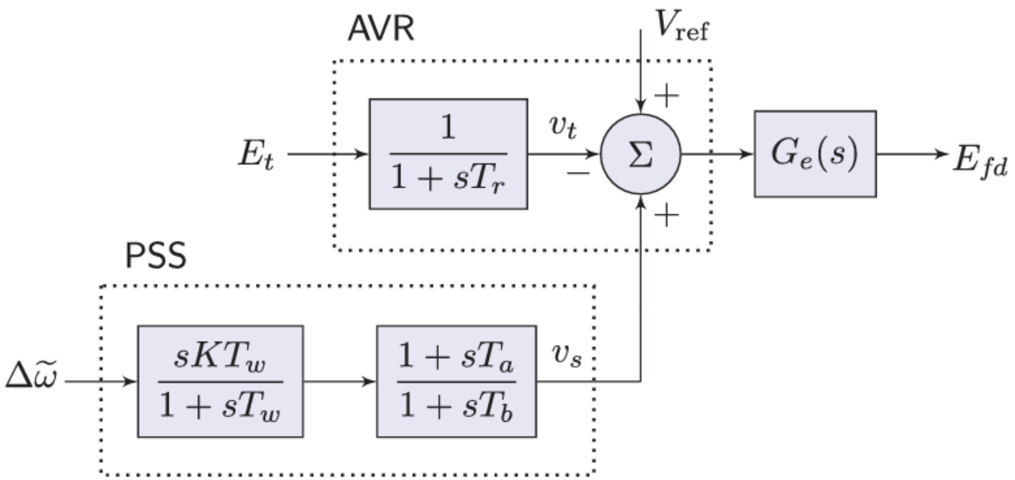
Parameter Values	Tuning Description
$\beta_1 > \beta_2$	Targets inter-area and local modes
$\beta_1 < \beta_2$	Targets the frequency regulation mode
$\beta_1 = \beta_2 \neq 0$	Standard $\Delta\omega$-type PSS
$\beta_1 = \beta_2 = 0$	No PSS control

Output equation of PSS

$$\Delta\nu(t) \triangleq \beta_1 \left[\omega_i(t) - \overline{\omega}(t)\right] + \beta_2 \left[\overline{\omega}(t) - \omega_0\right]$$

R. T. Elliott, P. Arabshahi, and D. S. Kirschen, ''A generalized PSS architecture for balancing transient and small-signal response,'' IEEE Trans. Power Syst., vol. 35, no. 2, pp. 1446–1456, Mar. 2020.

Δω-Type PSS



Control error

$$\Delta\widetilde{\omega}(t) \triangleq \widetilde{\omega}(t) - \omega_0$$

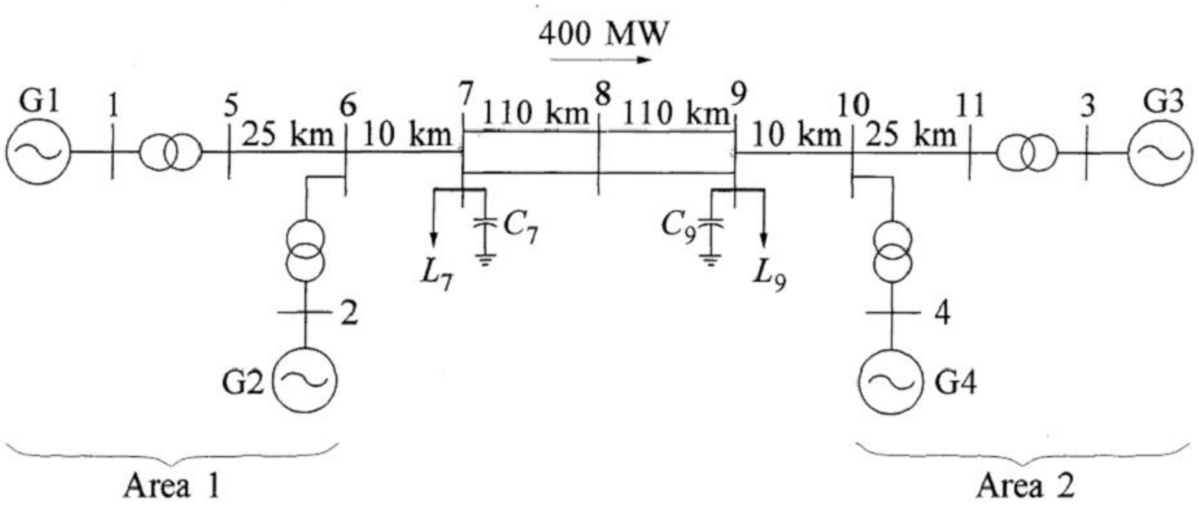
Feedback Signal

$$\widetilde{\omega}(t) = \begin{cases} (\beta_1/\beta_2)\left[\omega_i(t) - \overline{\omega}(t)\right] + \overline{\omega}(t), & \text{for } \beta_2 > 0 \\ \beta_1\left[\omega_i(t) - \overline{\omega}(t)\right] + \omega_0, & \text{for } \beta_2 = 0 \end{cases}$$

Key difference with other standard PSS models are use of global signal/WAMS signal for control than local signal

R. T. Elliott, P. Arabshahi, and D. S. Kirschen, ''A generalized PSS architecture for balancing transient and small-signal response,'' IEEE Trans. Power Syst., vol. 35, no. 2, pp. 1446–1456, Mar. 2020.

Simulation Setup



Kundur two area system with PSS on G2 and G3

R. T. Elliott, P. Arabshahi, and D. S. Kirschen, ''A generalized PSS architecture for balancing transient and small-signal response,'' IEEE Trans. Power Syst., vol. 35, no. 2, pp. 1446–1456, Mar. 2020.

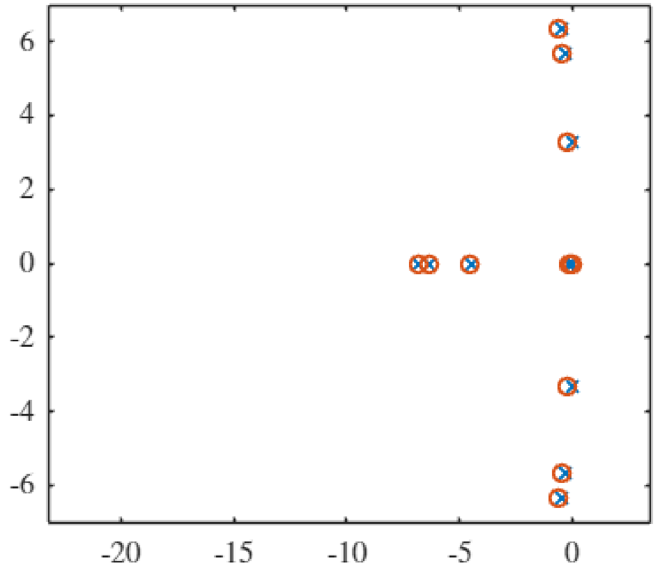
Simulation Results

Eigen Values	Frequency Mode	Damping Ratio
-0.42089 + 6.3554i	1.0115	0.0661
-0.42089 - 6.3554i	1.0115	0.0661
-0.28902 + 5.657i	0.9003	0.051
-0.28902 - 5.657i	0.9003	0.051
-6.8438 + 0i	0	1
-6.3271 + 0i	0	1
-4.4875 + 0i	0	1
-0.011982 + 3.3021i	0.5255	0.0036
-0.011982 - 3.3021i	0.5255	0.0036
-0.13194 + 0i	0	1
-0.10983 + 0i	0	1
-0.0173 + 0i	0	1
-0.0033303 + 0i	0	1
-0.0033331 + 0i	0	1
-0.0033332 + 0i	0	1
-100 + 0i	0	1
-100 + 0i	0	1
-100 + 0i	0	1

System without PSS

Eigen Values	Frequency Mode	Damping Ratio
-100 + 0i	0	1
-100 + 0i	0	1
-0.60018 + 6.3558i	1.0116	0.094
-0.60018 - 6.3558i	1.0116	0.094
-0.45734 + 5.6573i	0.9004	0.0806
-0.45734 - 5.6573i	0.9004	0.0806
-6.3172 + 0i	0	1
-6.827 + 0i	0	1
-4.4984 + 0i	0	1
-0.17707 + 3.3047i	0.526	0.0535
-0.17707 - 3.3047i	0.526	0.0535
-0.13455 + 0i	0	1
-0.12253 + 0i	0	1
-0.10255 + 0i	0	1
-0.087007 + 0i	0	1
-0.010801 + 0i	0	1
-0.0010286 + 0i	0	1
-0.0015182 + 0i	0	1
-0.0033266 + 0i	0	1
-0.0033331 + 0i	0	1
-0.0033332 + 0i	0	1
-100 + 0i	0	1

System with Δω-Type PSS



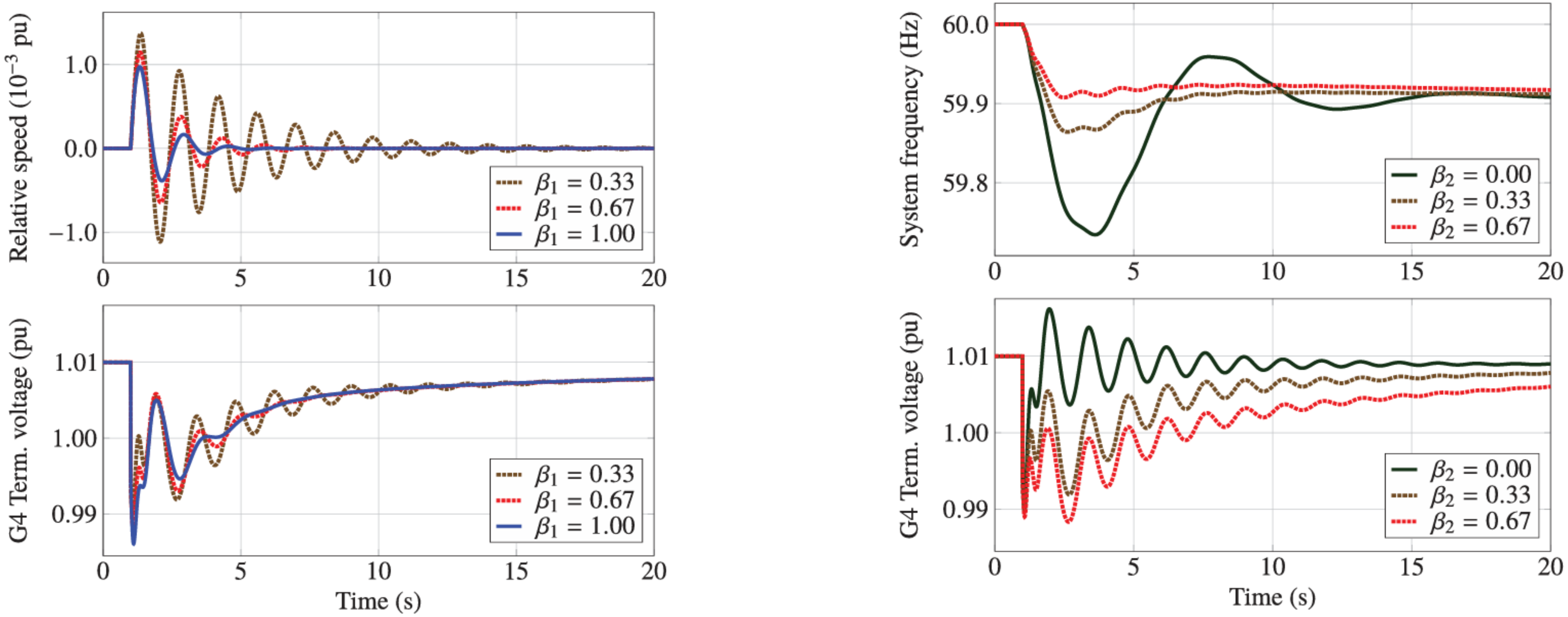
Eigen Value Comparison

Observations

- PSS was able to improve the system dynamics by a small margin
- All the frequency modes have achieved a damping greater than 5%
- However, introducing PSS introduced more modes into the system.

Transient Stability

Generation loss: Generator G3 tripped at 1 seconds



R. T. Elliott, P. Arabshahi, and D. S. Kirschen, ''A generalized PSS architecture for balancing transient and small-signal response,'' IEEE Trans. Power Syst., vol. 35, no. 2, pp. 1446–1456, Mar. 2020.

Conclusion

- Generalized PSS architecture improves system response effectively in grids.
- Research addresses present challenges in modern power systems effectively.
- Highlights the necessity for further exploration into PSS parameter tuning.

Thank You

Questions?