Power System Stabilizer Analysis in PowerWorld

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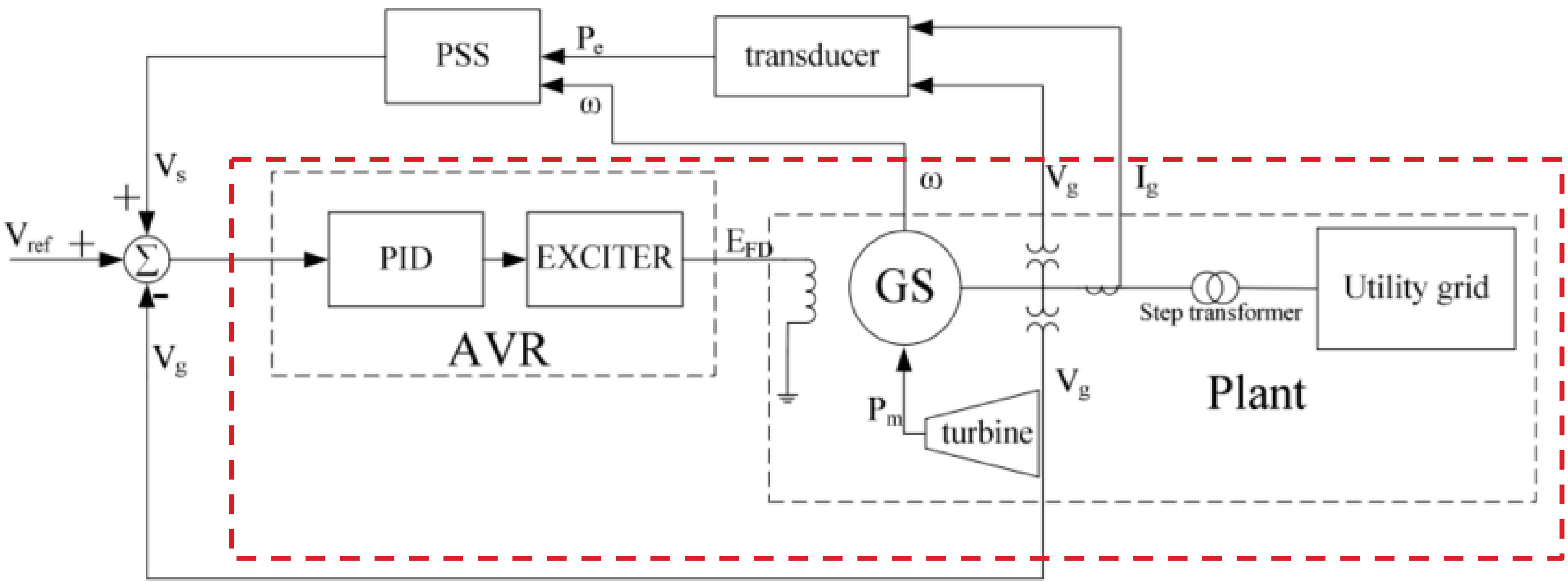
Overview

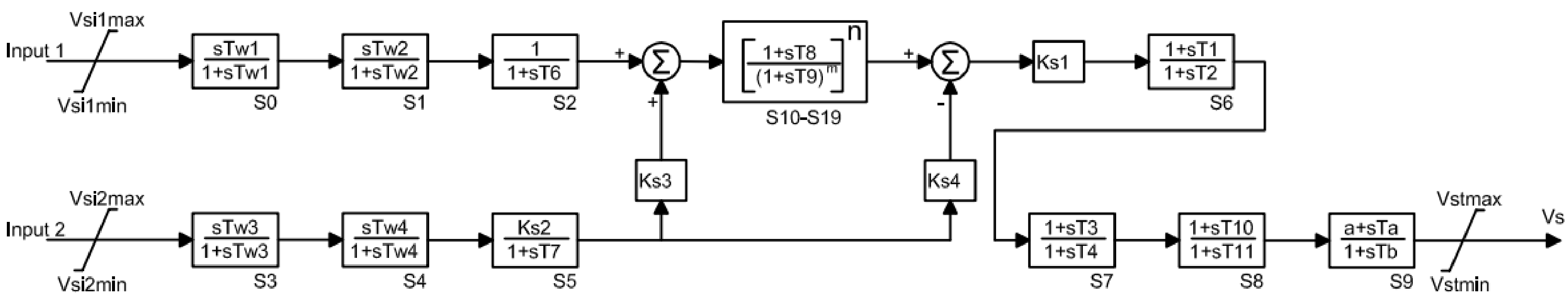
- GEP
- PSS
- VAR-501
- Modal Analysis method
- PSS compensation simulation
- Maximum practical gain simulation
- Stability in systems with high penetration of inverter based resources (IBRs)

WHAT IS GEP?

Generator, **E**xciter, and **P**ower System (GEP)



WHAT IS PSS?



- Located before the AVR
- Provides stabilizing damping to system by modulating Vref signal into AVR

Why is it needed?

- Three major types of oscillations
  - Inter-unit oscillations (1-3Hz)
  - Local mode oscillations (0.7-2Hz)
  - Inter-area oscillations (0.5Hz)
- If the AVR and damping torque of generator aren't enough to decrease oscillations, the system can become unstable
- PSS provides additional damping to the system, increasing stability

VAR-501 OVERVIEW

- GEP phase margin
  - Can be calculated, measured, or simulated
- Maximum Practical gain
  - Must be measured in the field according to the standard
- Washout time constants
  - Can be confirmed by looking at the PSS settings/parameters
- All these requirements ensure that the PSS is tuned to properly damp the system

GEP ANALYSIS ON SITE

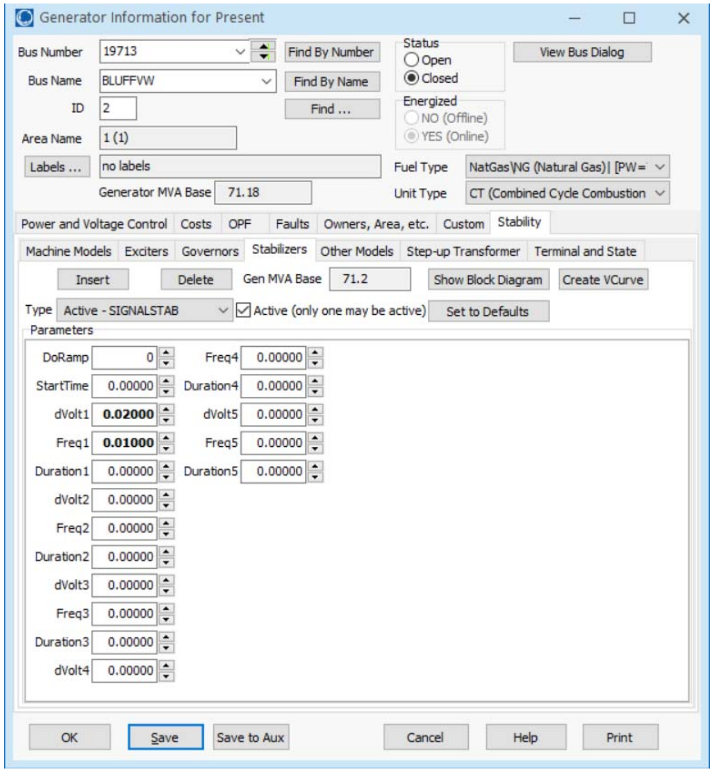
- Process
  - Turn off PSS
  - Inject white noise
  - Develop transfer function Vt/Vref
- What if testing isn't possible?

GEP analysis in PowerWorld

- Using the SIGNALSTAB model and the Modal Analysis feature of PowerWorld, the GEP response can be simulated using a positive sequence model
- A dynamic model that meets the MOD-026 and MOD-027 standards must be used
- Constant MVAR and MW setpoints must be used for each run

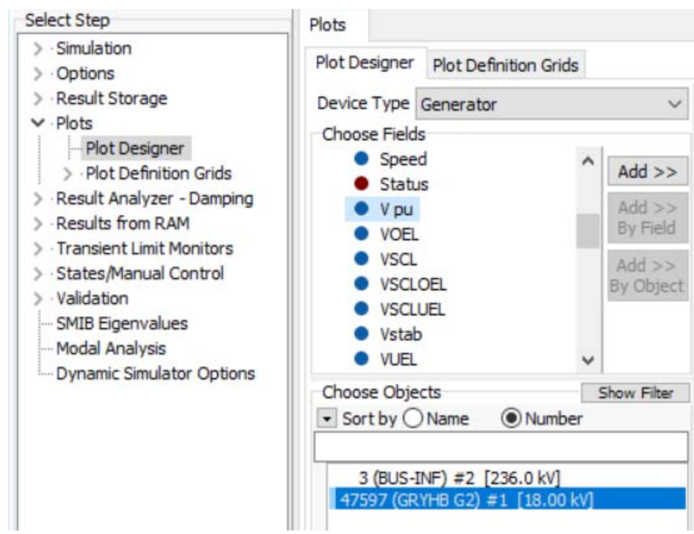
PROCEDURE

- In the generator information screen, disable PSS model and insert "SIGNALSTAB" model
- Ensure the SIGNALSTAB model is active
- Parameters "dVolt1" and "Freq1" should be set to 0.02V and 0.01Hz respectively
- Press save and exit the generator information screen



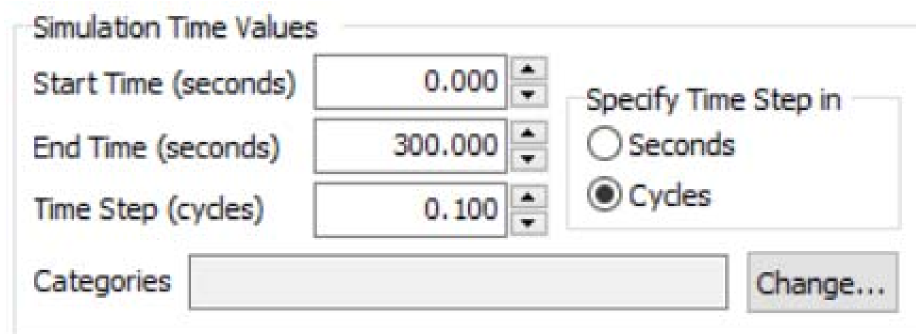
PROCEDURE (CONT.)

- Next, a plot that contains the necessary data should be created in the Transient Stability window. The generator "Vpu" and "Vstab" signals will need to be plotted together.



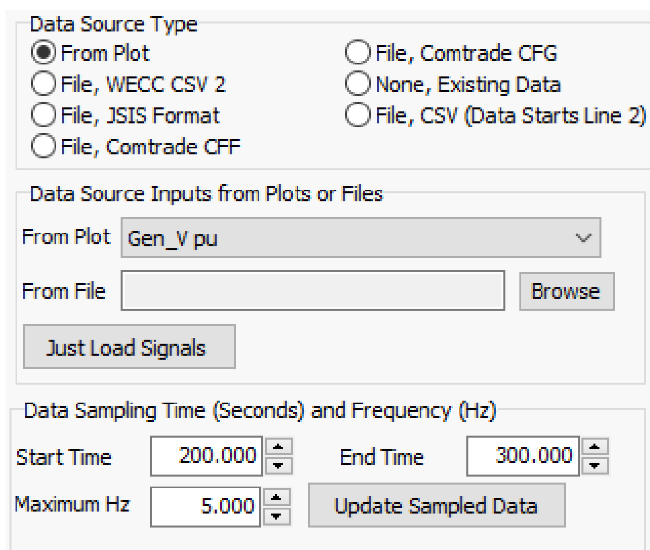
PROCEDURE (CONT.)

- Now a simulation can be run with the following simulation time values
- This simulation should be ran with no contingency elements



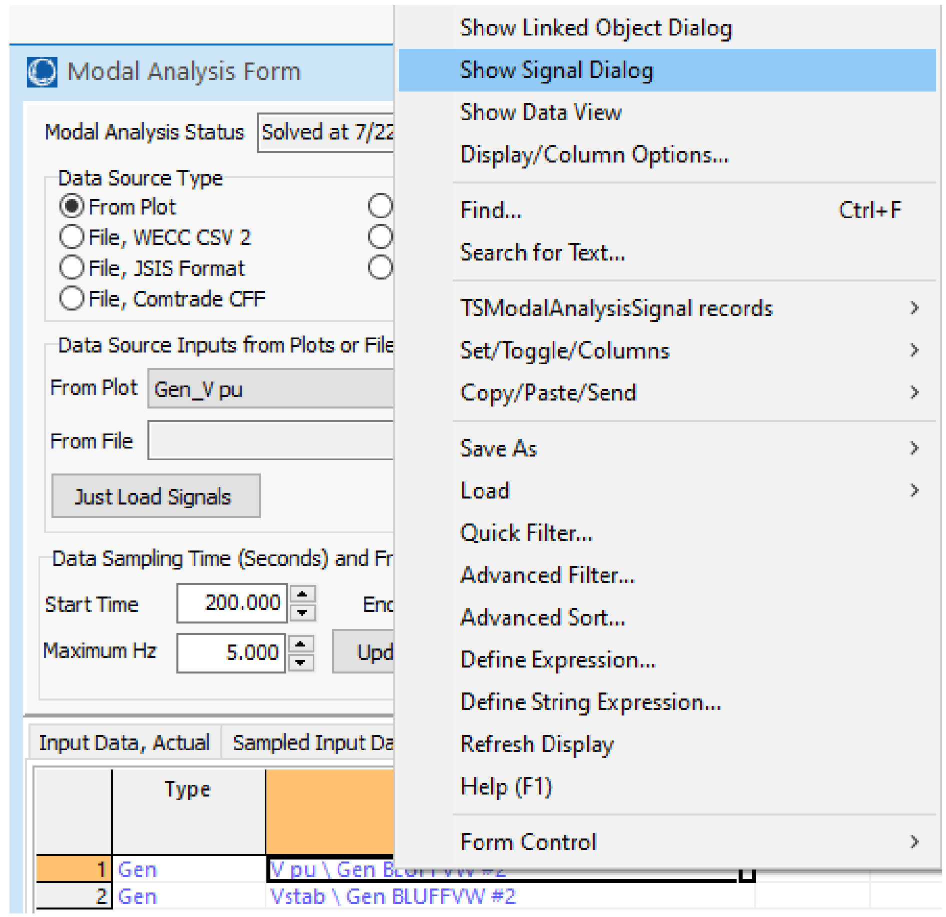
PROCEDURE (CONT.)

- In the modal analysis window select “From Plot” as the Data Source Type, and Gen_V pu in the “From Plot” drop down
- The configuration for .01 Hz can be seen below. Now Modal Analysis can be done by clicking the “Do Modal Analysis” button



Procedure (Cont.)

- After Modal Analysis is complete, right click on the V pu signal in the bottom window and select "Show Signal Dialog"



Procedure (Cont.)

- In the Signal Dialog window, select the "Modal Results" tab. From there the phase angle of the output signal can be seen. The same can be done for the Vstab signal.

Actual Input | Sampled Input | Fast Fourier Transform Results | Modal Results | Original and Reproduced Signal Comparison

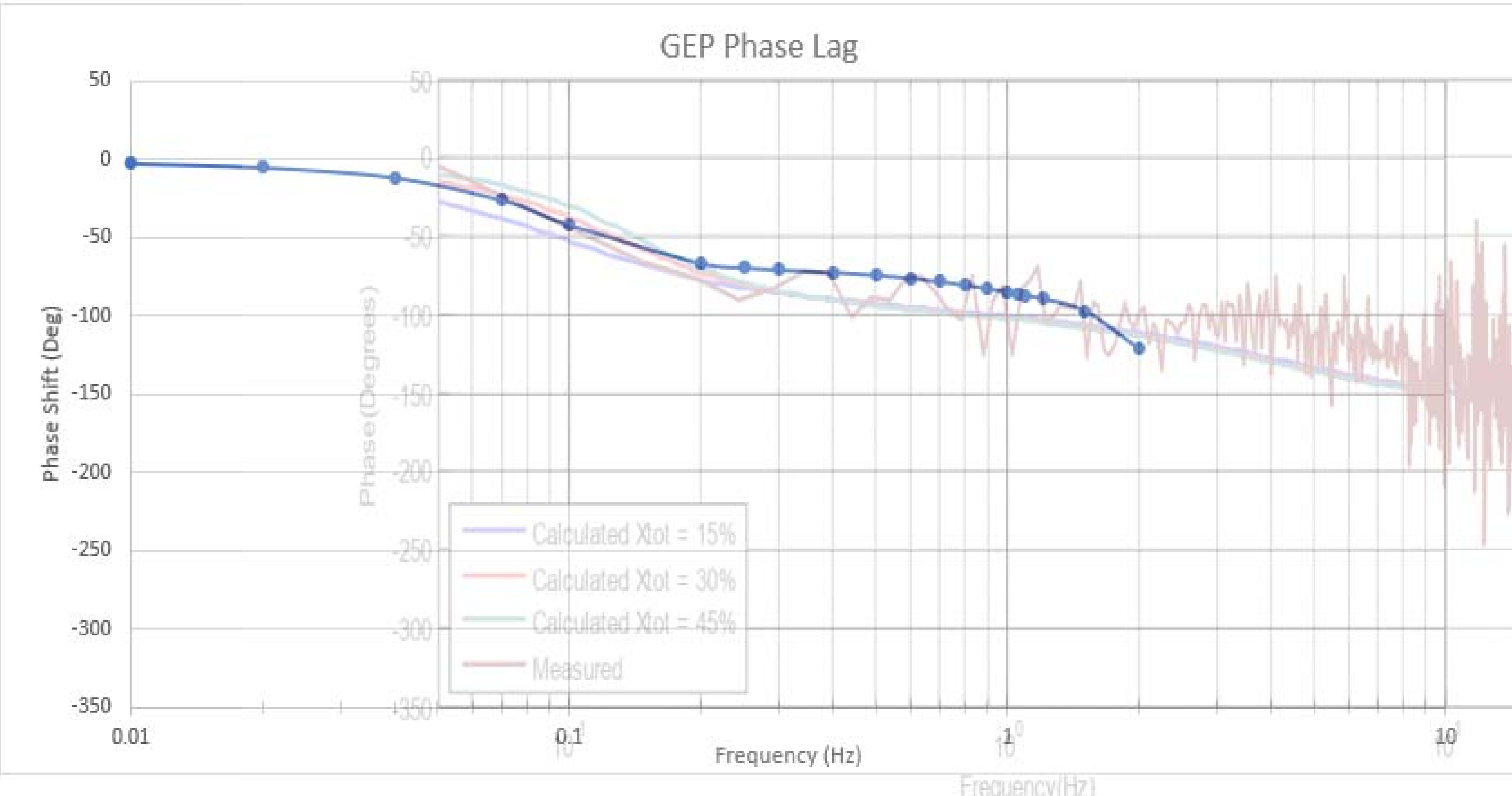
	Damping (%)	Frequency (Hz)	Magnitude Scaled by SD	Magnitude, Unscaled	Angle (Deg)	Lambda	Include in Reproduced Signal
1	-3.968	0.010	1.602	0.014	-116.39	0.003	YES
2	-100.000	0.000	0.417	0.004	0.00	0.014	YES
3	100.000	0.000	2.260	0.020	-180.00	-0.024	YES

- The difference between these two angles represents the phase shift between the two signals

Procedure (Cont.)

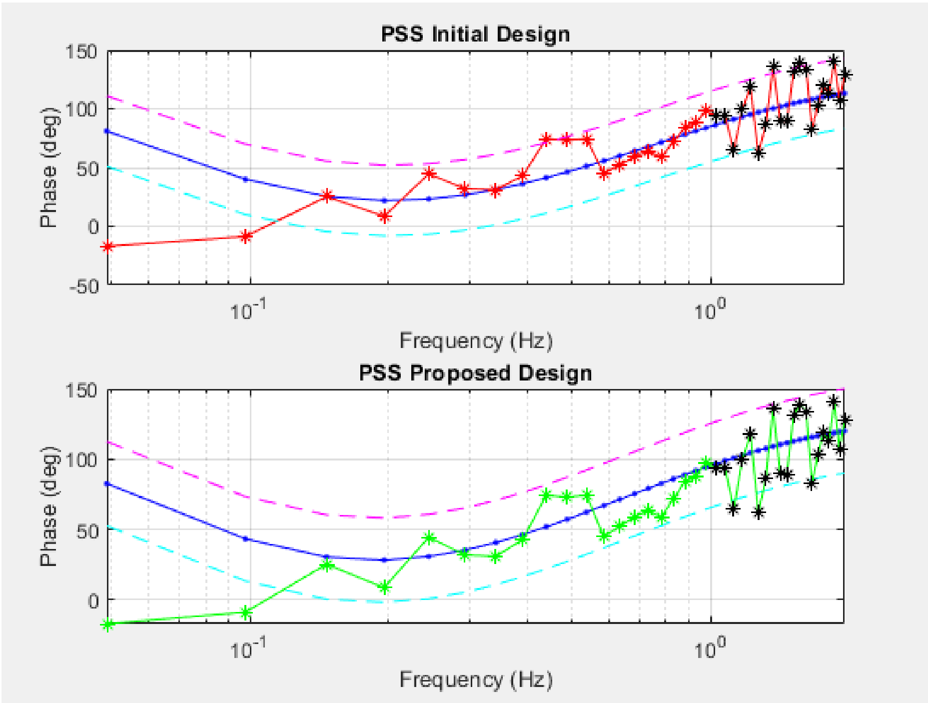
- The “Freq1” parameter of the SIGNALSTAB model can be incremented from .01-1.3Hz, the simulation reran, and the calculation of phase shift repeated in order to calculate the phase shift of the GEP throughout this frequency range
- If the model has been validated, this provides the same result as the GEP testing on site

MEASURED VS. SIMULATED GEP RESULTS



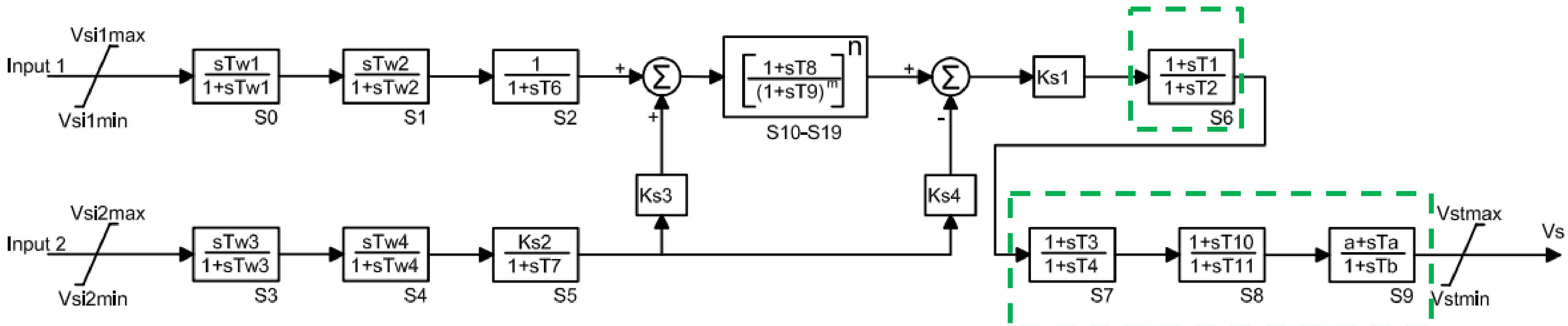
Simulating PSS Compensation

- Using proprietary tools to simulate the PSS compensation, a unit can be tested for compliance with R3.1 of the NERC VAR-501 standard



TUNING PSS

- Using the tool shown, the PSS can be tuned to meet VAR-501 R3.1
- It's important to only change the phase compensation parameters, boxed in green below, when tuning to meet R3.1
- It is also important to conduct pole analysis to determine if the new tuning is stable



Maximum Practical Gain

- When testing for maximum practical gain on site, the gain is increased until increased until oscillations can be observed at the output of the PSS or AVR.
- Increasing gain until oscillations occur can put the generator and other equipment at risk of damage, if the gain has to be increased to an unreasonable value
- The standard states that it is required to show field results used to determine the maximum practical gain. If in the future this requirement is removed, then the maximum practical gain could also be determined through simulation or calculation.

Benefits of Simulation

- Ability to test and tune PSS for VAR-501 R3.1 compliance remotely
- Can show up to site with more information and an idea of what to expect when testing
- Powerful and accurate simulation method
- Simulation prevents possibility of damage to equipment during on site testing

INVERTER BASED RESOURCES AND THE FUTURE OF GRID STABILITY

- Synchronous machines (SMs) provide damping torque and inertia to the grid. IBRs can also provide “virtual” damping torque and inertia, however the implementation of this is largely unexplored.
- Like SMs, if the IBRs don’t provide enough damping torque or inertia to damp oscillations, they could also benefit from a PSS-like system that provides additional damping. The use or design of these systems is again largely unexplored.

High IBR Penetration Effects on Grid

- The prevalence of inter-area oscillations (0.5Hz) are increased in systems where SMs are more dispersed
- As more SMs are replaced by IBRs, the need for additional damping from PSS will increase. As a result, we may see more areas require PSS on all SMs, or even new requirements for IBRs to provide additional damping for these inter-are oscillations.

Super-Synchronous Oscillations

- As the volume of IBRs increases, a new type of oscillation is observed. This oscillation is called super-synchronous and has a frequency range of approximately 10Hz to 3kHz.
- These oscillations are a result of the fast control loops used by IBRs, and are mostly observed between IBRs within close proximity to one another
- The oscillations are highly related to the parameters of the IBRs control loops, so design standards or tuning requirements may be implemented in the future to mitigate super-synchronous oscillations

CONCLUSION

- PowerWorld can accurately simulate the GEP response of a site needed to verify compliance with VAR-501
- PowerWorld can also potentially be used to verify the maximum practical gain, but simulation of gain tests is not allowed for VAR-501 compliance
- The increase in IBR penetration in North America will create a greater need for PSS and proper tuning to address oscillations in the grid

QUESTIONS?

References

[1] M.J. Gibbard, P. Pourbeik and D.J. Vowles, *Small-signal stability, control and dynamic performance of power systems*, University of Adelaide Press, Adelaide, 2015.

[2] Bixiang Tang, "Parameter Tuning and Experimental Results of Power System Stabilizer," May 2011.

[3] Global PST Consortium. (Oct. 2021). System Needs and Services for Systems with High IBR Penetration. [Online]. Available: https://ieeeauthorcenter.ieee.org/wp-content/uploads/IEEE-Reference-Guide.pdf