PSEC Application Notes

Power System Stabilizer Helps Meet Plant Stability Margins for Simple Cycle and Combined Cycle Power Plants

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The Power System stabilizer (PSS) is an optional control that is part of the excitation system for generator control. The PSS acts to modulate the generator field voltage to damp electrical power-speed oscillations. In many cases the PSS control is mandated by interconnection specifications or power pool policy. Perhaps the best example of this is the 25 year history that the PSS has had with generating units in the Western Systems Coordinating Council (WSCC).

The recent increase in orders for power plants has given rise to an increase in interconnection studies to insure these plants are integrated into the power systems. Stability studies are important to verify adequate transient and dynamic stability of the plant for electrical faults in the system. With the stability margins being determined by sometimes weak interconnections during contingency conditions, it can be difficult to insure adequate margins. With weak transmission systems there are often sustained power oscillations in the 0.7 - 1.0 Hz. range, following the clearing of electrical faults. In many cases the generating units tie into strong systems and the response is stable and well damped. From the perspective of the plant being added to the system the equivalent impedance looking out from the high voltage switchyard is,

$$Xe = \frac{MVA_{gen}}{MVA_{sc}}$$

the unit MVA base divided by the short circuit MVA at the high voltage bus. To this we need to add the step-up transformer impedance to get the total impedance seen from the generator. In many cases this total impedance is only slightly larger than the transformer impedance, typically in the range of 15-20% on the unit rating base. Such a strong impedance leads to stable well damped response with reasonably large stability margins. During contingency conditions, with lines and other generators out-of-service, the equivalent impedances can become much larger and hence reduce stability margins.

To explain the situation in a more analytical way, consider the root locus plot in Fig. 1. This shows a plot of the closed loop eigenvalue of a single generator system as the line reactance is changed and the AVR gain is varied. The position of the eigenvalue in the s-plane shows the relative dynamic stability of that operating point. For roots farther in the left half plane this corresponds to increased damping or positive

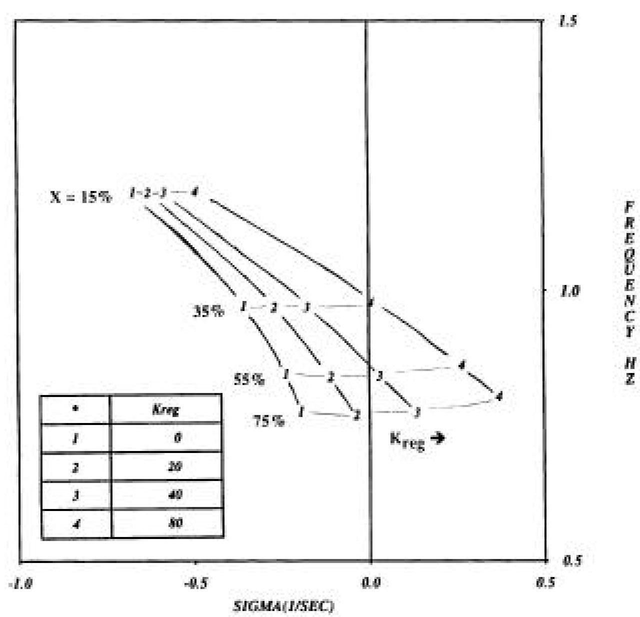

Fig. 1 - Effect of AVR Gain and System Strength on Dynamic Stability

dynamic stability margins. When the root gets closer to the jω axis, or in the right half-plane, indicates reduced dynamic stability, or actual instability. This figure clearly shows that as system reactance is increased (weaker transmission) or the AVR gain is increased (to help transient stability) the local mode oscillation is less well damped. At some point the combination of excitation transient gain and system reactance can result in a dynamically unstable system, without PSS control. Symbol 2 in the figure corresponds to a nominal transient gain of 20 which shows stable results for any equivalent system reactance. For higher transient gains there will be a point at which the unit will be unstable as the system becomes weaker. A dynamic instability results in growing oscillations from the unit, eventually resulting in the unit tripping due to the sustained oscillations impacting the unit protective relaying.

A recent example of a study of a combined cycle power plant shows the benefit of PSS in helping to meet stability requirements. The plant in this example is a multi-unit STAG plant with three GE 7FA combustion turbines with generators rated about 200MVA, and a 440MVA steam turbine generator supplied by a Heat Recovery Steam Generator (HSRG) from the combustion turbines exhaust. A simplified one-line diagram of the plant and system interconnections is Fig. 2, showing that the plant is connected at the end of a 345 kV transmission network. Power may also flow through two transformers, connecting to four 138 kV circuits.

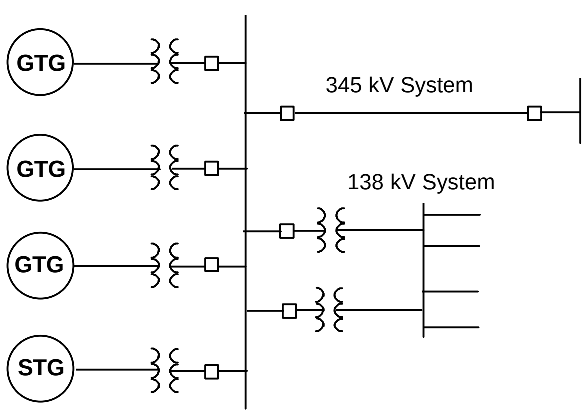

Fig. 2 - One-Line Diagram of the Simplified Study System

Under normal conditions, the total equivalent impedance seen from the studied plant is 0.55 pu. Fig. 3 shows the response of one of the three gas turbine-generators for a three phase fault on the plant end of the 345 kV line, cleared by opening the line in 6 cycles. Studies showed that all three gas turbine-generators can be stable with the PSS control, but it is necessary to trip the steam turbine generator to maintain transient stability. However, with the loss of the 345 kV line the total equivalent impedance becomes 1.1 pu, causing dynamic stability

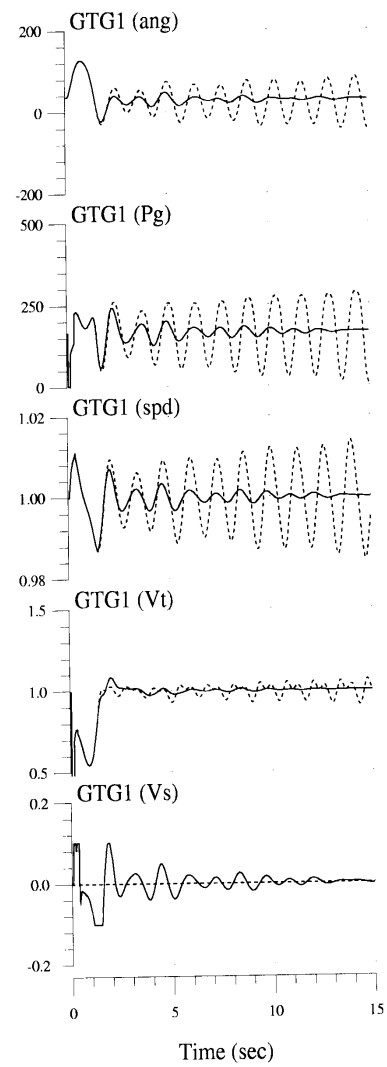

Fig. 3 - Response of a GT Generator With and Without PSS Controls

problems. The dotted traces in Fig. 3 indicate a lack of damping in one of the combustion turbine generators response, assuming the excitation system is not equipped with PSS. The solid traces show the response for the same disturbance, when the new units are all equipped with PSS. Clearly, the PSS control is critical in this case to insuring dynamic stability for the system in the contingency condition.

In summary, power system stabilizers should be considered carefully in the analysis of plant controls in stability studies. Although the PSS controls is always beneficial for stability, its action can become critical in cases where the system becomes weak due to lines out-of-service. GE-PSEC can offer a full range of services in aspects of plant stability

- Interconnection stability studies to investigate plant performance

- Tuning of excitation and PSS controls for best performance to meet system requirements and stability guidelines.

- Field test and site support during commissioning to verify the AVR/PSS studies and insure stability margins

For further information on PSEC services, contact GE Power Systems Energy Consulting, 1 River Road - Building 2, Schenectady, NY 12345 - Fax (518) 385-9529