

Impact of the Interactions Among Power System Controls

A Summary of Presentation at the
NSF/EPRI Workshop on Global Optimization

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Introduction

This presentation carries the same title as the CIGRE Task Force 38.02.16 [1]. The author's original intent was to present a summary of the work carried out by this taskforce, published in [1], and describing recent developments in small signal stability analysis and coordinated design of multiple controllers in power systems. Faster computer hardware, new methods of numerical linear algebra for systems and control, advanced control and system identification theory, visualization tools, intelligent systems and other techniques have enhanced the practical use of small signal stability analysis and controller design techniques in large scale power systems [1].

However, since the publication of the Cigre TF document [1], the author and colleagues [2,3,4] produced interesting work on this topic. This workshop was therefore seen as an opportunity for presenting these results to this selected audience of power system optimization and control experts and getting valuable feedback.

Presentation Contents

The presentation slides, available at the Workshop's Home page, are organized into the following sections:

1. Adverse effects on intra-plant modes caused by improperly designed power system stabilizers (PSSs).
2. Analysis of transfer function zeros to better understand the adverse terminal voltage transients induced by the presence of PSSs.
3. Hopf bifurcations in the control parameters space.

4. Simultaneous partial pole placement for power system oscillation damping control.

The slides in Section 1 contain an enlarged version of the material described in Chapter 2 of [1], being illustrated with various multivariable root-locus plots. This material is of a tutorial nature and shows that the center-frequency of the PSS phase-lead blocks should be set higher than those frequencies of the intra-plant modes. Otherwise, the intra-plant modes would get destabilized as the PSS gains were raised for the effective damping of inter-area modes.

The slides in Section 2 relate to an IEEE/PES Conference Proceedings paper [2] describing the drawbacks of using PSSs derived from terminal power in hydro units, due to the undesirable voltage transients at the generator terminal bus following rapid power changes during load pick up or generating-unit rejection. The abstract of this paper is transcribed:

“This paper studies the adverse impact on the transient performance of both generator terminal voltage and reactive power output caused by Power System Stabilizers (PSS). The analysis of the zeros of a transfer function different from that of the stabilization loop provides a better understanding of the adverse increase in terminal voltage and reactive power transients caused by PSSs. The relationship between the location of selected transfer function zeros and the PSS adverse effects is demonstrated.”

The slides in Section 3 relate to an IEEE Transactions of PWRs paper [3], to appear during 2003. The results in this paper relate to the design of the Power Oscillation Damping (POD) controllers of the two FACTS devices (thyristor controlled series compensators) installed at the two terminals of the Brazilian North-South 500 kV interconnection. The abstract of this paper is transcribed:

“This paper describes two algorithms for determining the value of a given system parameter that causes the crossing of a complex-conjugate eigenvalue pair through the small-signal stability boundary (Hopf bifurcation). A large-scale test system was utilized to validate the two proposed Hopf bifurcation algorithms. The results presented demonstrate the computational efficiency and numerical robustness of the algorithms.”

The slides in Section 4 relate to an IEEE/PES Conference Proceedings paper [4], whose abstract is transcribed below:

“This paper presents a methodology for simultaneous partial pole placement using the Newton-Raphson method and the information provided by the stabilizing control loop [$V_{pss}(s) / V_{ref}(s)$] transfer function residues associated with the critical eigenvalues. The use of the methodology of partial pole placement in the coordination of power system stabilizers is assessed using a test system.”

Future Developments

The development of highly automated computer tools is needed for the coordinated design of PSSs and PODs in large power systems, considering multiple loading scenarios and credible contingencies. Much of this program automation can be done by better exploiting methods already familiar to the power system dynamics and control community, but the development of new methods is still needed to maximize equipment utilization while ensuring robust performance.

Proper consideration of higher-frequency system dynamics into controller design models, mostly at the sub-synchronous range, becomes mandatory as the use of FACTS devices gets disseminated.

References

1. CIGRE Task Force 38.02.16 , “Impact of the Interactions Among Power System Controls”, Brochure No. 166, Paris, 2000.
2. J. C. Ferraz, N. Martins, N. Zeni, G. N. Taranto, “Adverse Increase in Generator Terminal Voltage and Reactive Power Transients Caused by Power System Stabilizers”, Proceedings of IEEE/PES Winter Meeting, New York, January 2002.
3. S. Gomes, N. Martins, C. M. J. Portela, “Computing Small-Signal Stability Boundaries for Large-Scale Power Systems”, IEEE Trans. on PWRs, no. PE-011PRS, to appear in 2003.
4. J.C. Ferraz, N. Martins, G.N. Taranto, “Simultaneous Partial Pole Placement for Power System Oscillation Damping Control”, Proceedings of IEEE/PES Winter Meeting, Columbus, July 2001.