

The Dominant Pole Spectrum Eigensolver

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Abstract: This paper describes the first partial eigensolution algorithm to efficiently and simultaneously compute the set of dominant closed-loop poles in any high-order scalar transfer function. The proposed algorithm is called the **Dominant Pole Spectrum Eigensolver (DPSE)**. The DPSE is a subspace iteration method, which operates on both left and right subspaces to produce better estimates for the dominant poles of the transfer function $F(s)$. The results presented are related to the study of low-frequency oscillations in a large power system dynamic model, but the proposed algorithm is completely general. Reduced-order models are effectively obtained with the use of DPSE, as shown in the paper.

Keywords: *small-signal stability, poorly-damped oscillations, power system dynamics, transfer function, control systems, model reduction, dominant pole spectrum, large-scale systems, sparse eigenanalysis.*

INTRODUCTION

The power system dynamics and control area has produced many important contributions to large scale eigenanalysis [1,2,3,4,5,6,7]. A brief review of the major eigensolution algorithms utilized in power system applications can be found in [8].

The well-known AESOPS algorithm [1] was designed to selectively compute the dominant oscillation modes in the torque-angle loop of a given generator of a multimachine system. A major advance on the AESOPS concept was made with the algorithm described in [6] which can efficiently compute the dominant closed-loop poles [9] of any specified high order transfer function $F(s)$. The algorithm in [6] has been used by the author and associates to track critical eigenvalues as system conditions or control parameters change [8].

Model reduction is an important issue to the control systems field and its applications in power system dynamics

[10,11,12,13,14]. Highly reduced models for power system transfer functions prove effective for controller design [12]. Once the dominant closed-loop poles are known, the associated transfer function residues can be efficiently computed [15]. From this information, one can build reduced-order transfer function models whose accuracy improve as more dominant poles are considered.

The following questions were recently raised in the written discussions of [6]: How can one be sure that all dominant closed-loop poles have been found? Can one envision the development of a more powerful algorithm, which simultaneously computes all the dominant poles? The answers to these questions are given in this paper in the form of a powerful algorithm for the simultaneous computation of the dominant closed-loop poles of a chosen scalar transfer function. The algorithm of this paper will be called the **Dominant Pole Spectrum Eigensolver (DPSE)**.

The computational performance of the DPSE in the solution of a large power system problem is presented. Current eigensolution algorithms for large, practical power system problems operate on the sparse, non-reduced Jacobian [2,3,4,5,6,7], but for the sake of brevity the DPSE is here described as directly operating on the quite dense state matrix A .

ALGORITHM DESCRIPTION

The DPSE was developed from the combination of two recent algorithms:

1. The Refactored Bi-Iteration (RBI) [7], a subspace iteration method derived from the Bi-Iteration algorithm [16,17,18], but employing multiple moving-shifts;
2. The Dominant Pole Algorithm [6], a one-eigenvalue-at-a-time method which computes the dominant closed-loop poles in the transfer function $F(s)$.

The DPSE is presented in the flow chart of Figure 1. The RBI algorithm was described in [7] with a similar flow chart. The DPSE is a subspace iteration method, which operates on both left and right subspaces to produce better estimates for the dominant poles of $F(s)$. The scalar transfer function $F(s) = \mathbf{c}^T \cdot (s\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{b} + d$ need be expressed in matrix form as described in both Figure 1 and reference [6]. The term 'd', called the direct transmission element [9], is readily considered by the DPSE but it is here assumed to be zero for simplicity.

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