

Abstract—A theoretical basis and signal-processing approach for estimating a power system's electromechanical mode-shape properties using time-synchronized phasor measurements are presented. The relationship between modal eigenvectors and measurable power system quantities are derived. Spectral correlation analysis is used to implement the approach with demonstrative examples. This includes simulation examples as well as measured data from the western North American power system.

Index Terms—Electromechanical dynamics, mode shape, smallsignal stability, synchronized phasor measurements.

I. Introduction

Time-synchronized measurements provide rich information for estimating a power system's electromechanical modal properties via advanced signal processing. This information is becoming critical for the improved operational reliability of interconnected grids [1]. A given mode's properties are described by its frequency, damping, and shape. Recently, many publications have offered algorithms for estimating the modal frequencies and damping from time-synchronized measurements, including near real-time applications (see references in [2]). But, very few have considered the mode shape. This paper presents a theoretical connection between the eigenvector properties of a system and measurable spectral properties. Using this connection, an approach for estimating modal shape using spectral analysis of the synchronized phasor measurements is presented.

Similar to the modal damping and frequency information, near real-time operational knowledge of a power system's mode-shape properties may provide critical information for control decisions. For example, modal shape may someday be used to optimally determine generator and/or load tripping schemes to improve the damping of a dangerously low-damped mode. The optimization involves minimizing load shedding and maximizing improved damping.

Estimating the shape properties of a mode can be accomplished using two basic approaches: eigenanalysis of a smallsignal model [3]; or as shown in this paper, signal processing of time-synchronized measurements. An important advantage of the measurement-based approach is that the mode-shape estimates are based directly upon system measurements without the dependence on a large complex system model. Spectral correlation analysis has been routinely employed to analyze dynamic tests conducted in the western North American power system [4], and it has been related to transfer function properties and applied to power system data in [10]. Researchers have also used ring-down analysis (such as Prony analysis) to estimate mode-shape properties (e.g., [4] and [11]). But, no connection has been established between such analysis and the eigensolution of the system. This paper provides this connection.