A Proposal for Allocating PMUs for Monitoring Critical Oscillation Modes in the Mexican System

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Abstract: As a result of the deregulation and restructuring processes, the electric industry has experienced dramatic changes. Reorganization into generation, transmission and distribution units is the present trend worldwide. The continuous growth of the electricity consumption and the big difficulties for building new transmission lines is forcing to operate the power system closer to their security limits. Since the system reliability must be maintained, no matter how stressed is the operating condition. Electric utilities are employing state-of-the-art technology to monitor critical indexes to ensure a secure operation of the system. This paper proposes an approach to allocate PMUs for monitoring critical oscillation modes in a power system. The approach is based on Modal and Prony analysis and the paper reports the application of this in preliminary studies for creating a Wide Area Measurement System in the Mexican Power System aimed to monitor critical oscillation modes.

Keywords: Modal Analysis, Prony Analysis, Power Systems, PMUs.

1. INTRODUCTION

In the last two decades, the electric industry has undergone through deregulation and restructuring processes. As a consequence of these changes, electric utilities worldwide are being reorganized into generation, transmission and distribution units. In addition, the continuous growth in the electricity consumption, the environmental and the economical constraints for building up new transmission lines together with the growing number of independent power generators increasing the power systems generation, are forcing to operate them closer to their security limits (Bhargava, et., al. 2008 ; Karlsson, et., al. 2004; Thorp, et., al, 2008). As a consequence of this, the systems have become more sensitive to failure occurrence and its daily operation has also turned more complex than ever before (Xiao, et., al. 2004).

Since maintaining high reliability levels of the power system, while operating under stressed conditions not experienced before, is a fundamental issue, electric utilities are employing state-of-the-art technology to provide system operators with faster and reliable means for monitoring the system performance.

Technological advances in communications, computers and Global Positioning Systems (GPS) have encouraged electric utilities to implement Wide Area Measurement Systems (WAMS) based on Phasor Measurement Units (PMUs), for real-time monitoring some indexes (defined as critical for the power system security (Ayuev, et., al 2008). An excellent review of a number of WAMS initiatives in different countries may be found in (Phadke, A. g., et., al., 2008)

Monitoring of power system oscillations modes, particularly those identified as low damped, is important in the operation and control of power systems, since poorly damped oscillations can cause cascading tripping events that eventually may lead to a system black-out (Andersson, G., et., al., 2005; Ayuev, et., al 2008).

From 1990 to date, a number of PMUs have been installed in power systems around the world. The aim of those initial installations were diverse, monitoring function and evaluation of the new technology were some of them (Phadke, A. G., et., al., 2008; Thorp, et., al, 2008; Silva-Peruyero, et., al., 2006). At present, new installations of PMUs are targeted to the creation of WAMS, from the measurements obtained at different points in the system, with the aim of improving the whole power system reliability.

Fundamental issues when implementing WAM Systems are the effective choice of locations for PMUs placement and the development of suitable monitoring functions that adequately support the power system operator decisions under abnormal operating conditions. In other words, the “optimal” location of PMUs for an specific purpose, i.e. state estimation, may not be an “optimal” locations for another purpose, i.e. monitoring of poorly damped oscillations (Xu, B., et., al., 2005).

This paper reports a proposal for locating PMUs in the Mexican System aimed to monitoring the damping of “critical” oscillations modes.

2. THE MEXICAN POWER SYSTEM

2.1 System Description

For management purposes, the Mexican Power System is divided in eight control areas (named Baja California, Central, Noreste, Noroeste, Norte, Occidental, Oriental and Peninsular) and a National Management Energy Centre.

The control areas coordinate the operation at regional levels and the National Management Energy Centre, where the overall operating policies and security limits are established. A geographical layout or the Mexican Power System is shown in Fig. 1. The Baja California regional system is isolated from the other regional systems.

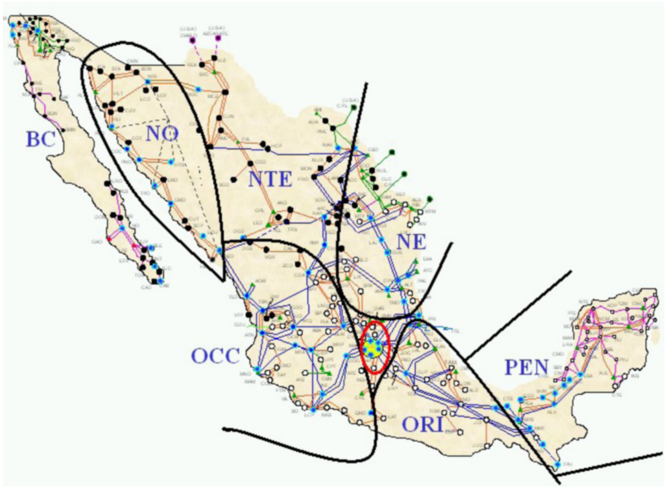

Fig. 1. Geographical layout of the Mexican Power System.

Problems with poorly damped oscillations in the Mexican System have been reported in the past. Before 2005 this problems had avoided the interconnected operation of the Northwest (NO) regional system with the others (NTE, OCC, ORI, CENTRAL, NE and PEN). As a result of a number of analysis, it was found out that an adequate retuning of the existing Power System Stabilizers (PSSs) of generator units located in the Northwest system (NO) would yield an important improvement in damping of those oscillations, allowing the interconnection of this regional system with the rest. A detailed description of this subject is reported in Flores, J. G., et., al., 2007.

With the aim of preventing severe problems in the Mexican power system associated with low damped oscillation modes, the Mexican utility is interested in developing a WAM system to provide the system operators with information regarding the damping associated with critical oscillation modes. The methodology for identifying the critical oscillation modes is described in the next section.

3. IDENTIFYING CRITICAL OSCILLATION MODES

Identification of critical oscillation modes in a power system may be performed using different approaches. Modal analysis is one of those approaches that have proved to be very effective for identifying the critical system modes and the most influential system variables on the mode composition. This approach is based on the linearization of the nonlinear equations that represent the dynamics of the power system around an operating point. Typical results from modal analysis are frequency, damping and mode-shape. However, applying this approach to characterizing the dynamical performance of large scale power system may become too slow. Thus, it is not suitable for on-line monitoring. Interested readers are referred to Kundur, P., 1994, for a detailed description of such approach. On the other hand, Prony analysis has proved to be a suitable approach for identifying dominant modes from time domain signals. This approach decomposes the signal into a sum of damped sinusoids, each characterized by the following parameters; amplitude, phase, frequency and damping. Furthermore, the approach may deal with the nonlinearities of the power system. Since, Prony method only analyzes the signal (system response) the size of system model is not a limitation for using it for real-time analysis. Interested readers on the subject are referred to Trudnowski D. J. (1999).

In this paper, both approaches were applied through the use of SSAT and TSAT software packages (DSA Tools User's Manual, 2007). The modal analysis was used for identifying the poorly damped oscillation modes, critical modes, of the system and choosing suitable locations for placing PMUs to monitor them. While, Prony analysis was used for computing the damping associated to the critical modes from time domain system response following to disturbance in the system.

For security reasons, any oscillation mode with a damping ratio less than 3 per cent in the Mexican System is considered as critical. With this in mind, the identification of those modes was carried out as follows;

a).- Compute all the system modes with a damping ratio less than 3 per cent.

b).- Identify the system state variables with the higher participation on those modes.

c).- Perform time domain simulations for a number of contingencies. Then, estimate the modal content of the time domain responses associated with the system variables identified in step (b) and the associated with the power flows on the inter-regional tie lines, using Prony analysis.

d).- Choose as suitable places those where the frequency associated with the critical mode(s) may be adequately observed from the spectral analysis performed on the time responses in step (c).

e).- Should more than one place be suitable for monitoring the critical mode(s), choose the one that may allow the monitoring of another index considered important for the system security.

4. TEST RESULTS

Theoretical results reported in this section may serve as guidance for identifying suitable locations of PMUs creating a WAM system aimed to monitor the damping associated