

Flexible Tool for Small Signal Stability Analysis.

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Abstract— This paper presents the development of a flexible tool for the calculation of the state matrix A of the power system. This program is called SIAM (*Sistema Informático para Análisis Modal - Computational System for Modal Analysis*). The state matrix is obtained from the load flow solution data and from the dynamic model parameters employed. The detailed models of synchronous machines, automatic voltage regulators and power system stabilizers are linearized for the calculation. To evaluate the method proposed, there is a comparison of results between SIAM and a commercial program for a reference case published.

Index Terms — Inter-area oscillation – Modal Analysis - Mode Oscillation – Power system stability - Small Signal Stability.

I. INTRODUCTION

The modal Analysis determines the eigenvalues or modes of oscillation of the system, expressed in terms of their frequency and damping. For modal analysis, the system state matrix A is required. This matrix is composed by the partial derivatives of the state variables referred to each other [1].

In studies carried out over the Argentinean interconnected power system (SADI-SIP), the state matrix is obtained from the same nonlinear models used for transient stability studies [2]-[3]. The dynamic model database is managed by the transmission system operator (CMMESA) and is available only for the commercial program PSS/E (hereinafter referred as Commercial Program - CP). This implies some limitations to perform specific analysis on the power system.

For more flexibility, a program under MATLAB was developed to build and to process the state matrix, instead of the specific module on the CP package. This program was called SIAM.

SIAM was developed to obtain a more versatile tool for studies of small signal stability. This tool can be used not only to calculate the eigenvalues and eigenvectors, but also to obtain the participation factors, mode shape, controllability and observability indices such as the residues. These features allow the design of different control strategies to avoid instabilities.

This program has the additional advantage of being able to perform the analysis based on a load flow solution without the need to migrate all data to any new software. In this case it is used a specific CP, but it could be used with any other. Additionally to the load flow solution data, it only needs to

know the dynamic model parameters employed. The actual version of SIAM contains more than 100 types of standard and user developed models to represent the synchronous machine (SM), Automatic Voltage Regulator (AVR) and Power System Stabilizer (PSS). New models could be included easily.

Another advantage of the SIAM is the analytical method of derivative calculation, which allows the use of highly nonlinear models with a bounded mistake. When the incremental method is used (step-type disturbance on the state variables for the derivative computation), there are greater errors which could spoil the analysis. This is due to the high gains and the existence of nonlinearities.

II. DIFFERENTIAL-ALGEBRAIC MODEL

A. Description

The dynamic behavior of a power system can be described by a set of nonlinear differential equations called Differential-Algebraic Equations (DAE) shown in (1):

$$\begin{aligned} \dot{x}_d &= f(x_d, x_a, u) \\ 0 &= g(x_d, x_a, u) \\ y &= h(x_d, x_a, u) \end{aligned} \quad (1)$$

where f represents the dynamic characteristic of the system components, while g represents the nonlinear network equations. The state variables x_d belong to generator models and control elements in the system, such as AVR and PSS. For this analysis, the algebraic variables x_a are the injected currents (\hat{I}_g) by the generators and the voltages on each node ($\hat{U} = Ue^{j\theta}$).

The h function represents the output behavior and u are the independent inputs. Both, h and u are considered null for this first analysis. At the same time, g consists of two functions, one describing the link between the generator stator and the grid (g_1) and another corresponding to the relations between network nodes (g_2). These two functions are called Stator Equations and Network Equations respectively [4]. With these assumptions, (1) can be described as (2):

$$\begin{aligned} \dot{x} &= f(x, \hat{I}_g, \hat{U}) \\ 0 &= g_1(x, \hat{I}_g, \hat{U}) \\ 0 &= g_2(x, \hat{I}_g, \hat{U}) \end{aligned} \quad (2)$$

The f function contains the fields and mechanic equations of the SM according to the desired degree of detail. Also, it included the differential equations of the AVR and PSS [1], [4]-[6].

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