Electrical Power and Energy Systems 33 (2011) 1031–1042

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Optimal location and signal selection of UPFC device for damping oscillation

N. Magaji *, M.W. Mustafa

Department of Electrical Engineering Bayero University, Kano Nigeria and Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Skudai, Malaysia

ARTICLE INFO

Article history:
Received 13 October 2009
Received in revised form 14 December 2010
Accepted 1 January 2011
Available online 12 February 2011

Keywords:
UPFC
Power system oscillations
Linear models
Eigenvalues
HSV
RHP zeros and residues factors

ABSTRACT

Unified power flow controller (UPFC) is used for controlling the real and reactive power in transmission line and bus voltage simultaneously and independently. An additional task of UPFC is to increase transmission capacity as result of power oscillation damping. The effectiveness of this controller depends on its optimal location and proper signal selection in the power system network. A residue factor has been proposed to find the optimal location of the UPFC controllers and eigenvalue analyses are used to assess the most appropriate input signals (stabilizing signal) for supplementary damping control of UPFC to damp out the inter-area mode of oscillations. The proposed residue factor is based on the relative participation of the parameters of UPFC controller to the critical mode. A simple approach of computing the residue factor has been proposed, which combines the linearized differential algebraic equation model of the power system and the UPFC output equations. While for signal selection a right-half plane zeros (RHP zeros) and Hankel singular value (HSV) is used as tools to select the most receptive signal to a mode of the inter-area oscillation. The placements of UPFC controllers have been obtained for the base case and for the dynamic critical contingences. The effectiveness of the proposed method of placement and selection of signals are demonstrated on practical network of TNB 25 bus system of south Malaysian network and New England 39 bus system.

1. Introduction

Damping of electromechanical oscillations between interconnected synchronous generators is necessary for a secure system operation. While local oscillations relating one or more generators swinging against the rest of the system are mainly predisposed by a restricted number of local system parameters, the behavior of low frequency inter-area oscillations is generally determined by global parameters of larger parts of the power system. Power system stabilizers (PSSs) applied on selected generators can effectively damp local oscillation modes. Their limited influence on inter-area modes, however, leads us to the fact that they may not be considered as the only solution to damp inter-area oscillations. Flexible AC transmission systems are being increasingly used to better utilize the capacity of existing transmission systems.

FACTs is a power electronics based technology that help the utility industry to deal with challenges in the power delivery business. A major thrust of FACTS technology is the development of power electric based systems that provide dynamic control of the power transfer parameters transmission voltage, line impedance and phase angle [1].

UPFC has control over all the parameters (voltage, impedance and phase angle) affecting power flow on the transmission line [1,2,31]. Application of FACTS devices for evaluating system damping using various techniques are reported in the literature [3–9], and the usefulness of damping the oscillations depends on the location of UPFC controllers. Several methods have been proposed for the placement of FACTS controllers. The proposed method by the authors [10–14,31] considered only static criterion based on improving power transfer, available transfer capability, etc.

The selection of appropriate feedback signal to FACTS controllers and effective tuning for improving the damping controls is an important consideration. According to [3,15,16] the most suitable supplementary input signals are locally measured transmission line-current magnitude or locally measured active power. Lee and Liu [17] and Zhou [18] used generator angular speed as a supplementary input signal.

Sadikovic and Anderson [19] used residue, called location index for effective damping, to find suitable location for damping inter-area mode of oscillations. The authors used only UPFC placement based on only single operating condition.

Farsangi et al. [20,21] proposed a method for selecting suitable feedback signal to FACTS controllers for improving the damping. The author used the minimum singular values (MSV), the right-half plane zeros (RHP zeros), the relative gain array (RGA) and the Hankel singular values (HSV) as indicators to find stabilizing

* Corresponding author. Address: Department of Electrical Engineering, 3011 Bayero University, Kano, Nigeria. Tel.: +234 8031850106; fax: +234 6075535903.
E-mail addresses: nmagaji2000@yahoo.com (N. Magaji), wazir@fke.utm.my (M.W. Mustafa).

0142-0615/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijepes.2011.01.020