Available online at www.sciencedirect.com

SCIENCE DIRECT®

Electric Power Systems Research 73 (2005) 177–185

ELECTRIC POWER SYSTEMS RESEARCH

www.elsevier.com/locate/epsr

Analysis and assessment of STATCOM-based damping stabilizers for power system stability enhancement

M.A. Abido*

Electrical Engineering Department, King Fahd University of Petroleum and Minerals, KFUPM Box # 183, Dhahran 31261, Saudi Arabia

Received 1 April 2004; received in revised form 6 July 2004; accepted 10 August 2004
Available online 1 December 2004

Abstract

Power system stability enhancement via STATCOM-based stabilizers is thoroughly investigated in this paper. This study presents a singular value decomposition (SVD)-based approach to assess and measure the controllability of the poorly damped electromechanical modes by STATCOM different control channels. The coordination among the proposed damping stabilizers and the STATCOM internal ac and dc voltage controllers has been taken into consideration. The design problem of STATCOM-based stabilizers is formulated as an optimization problem. For coordination purposes, a time domain-based multiobjective junction to improve the system stability as well as ac and dc voltage regulation is proposed. Then, a real-coded genetic algorithm (RCGA) is employed to search for optimal stabilizer parameters. This aims to enhance both rotor angle stability and voltage regulation of the power system. The proposed stabilizers are tested on a weakly connected power system with different disturbances and loading conditions. The nonlinear simulation results show the effectiveness and robustness of the proposed control schemes over a wide range of loading conditions. It is also observed that the proposed STATCOM-based damping stabilizers extend the critical clearing time (CCT) and enhance greatly the power system transient stability.

Keywords: Power system stability; Low frequency oscillations; Statcom and genetic algorithms

1. Introduction

Since 1960s, low frequency oscillations have been observed when large power systems are interconnected by relatively weak tie lines. These oscillations may sustain and grow to cause system separation if no adequate damping is available [1–3].

Although PSSs provide supplementary feedback stabilizing signals, they suffer a drawback of being liable to cause great variations in the voltage profile and they may even result in leading power factor operation under severe disturbances. The recent advances in power electronics have led to the development of the flexible alternating current transmission systems (FACTS) [4]. Generally, a potential motivation for the accelerated use of FACTS devices is the deregulation environment in contemporary utility business. Along with primary function of the FACTS devices, the real power flow can be regulated to mitigate the low frequency oscillations and enhance power system stability. This suggests that FACTS will find new applications as electric utilities merge and as the sale of bulk power between distant and ill-interconnected partners become more wide spread. Recently, several FACTS devices have been implemented and installed in practical power systems such as static VAR compensator (SVC), thyristor controlled series capacitor (TCSC), and thyristor controlled phase shifter (TCPS) [5–7]. The emergence of FACTS devices and in particular gate turn-off (GTO) thyristor-based STATCOM has enabled such technology to be proposed as serious competitive alternatives to conventional SVC. From the power system dynamic stability viewpoint, the STATCOM provides better damping characteristics man the SVC as it is able to transiently exchange active power with the system [8]. A little work has been done on the coordination problem investigation of the STATCOM-based damping stabilizers and the STATCOM internal ac and dc voltage controllers.

---

* Corresponding author. Tel.: +966 3 8604379; fax: +966 3 8603535.
E-mail address: mabido@kfupm.edu.sa.

0378-7796/$ – see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsr.2004.08.002

A multivariable design of STATCOM ac and dc voltage control was presented in [9]. The coordination between the ac and dc voltage PI controllers was taken into consideration. However, the structural complexity of the presented multivariable PI controllers with different channels reduces their applicability. Moreover, the utilization of damping capability of the STATCOM has not been addressed. The STATCOM damping characteristics have been addressed in [10–17]. However, the coordination among the STATCOM damping controllers and ac and dc voltage PI controllers has not been investigated.

In this study, a comprehensive assessment of the effectiveness of the STATCOM damping stabilizers when applied in coordination with the STATCOM internal ac and dc voltage controllers has been carried out. At first, a controllability measure based on singular value decomposition (SVD) is used to identify the effectiveness of each control input on the electromechanical mode of oscillations. To enhance power system dynamic stability and voltage regulation, coordination among the proposed STATCOM damping stabilizers and its internal ac and dc voltage controllers is taken into consideration. The controller design problem is transformed into an optimization problem where the real-coded genetic algorithm (RCGA) is employed to search for the optimal settings of stabilizer parameters. The nonlinear simulation results have been carried out to demonstrate the effectiveness and robustness of the proposed stabilizers to enhance system dynamic and transient stability. In addition, the potential of the proposed STATCOM-based damping stabilizers to extend the critical clearing time (CCT) and enhance the power system transient stability has been demonstrated.

2. Power system model

2.1. Generator

In this study, a single machine infinite bus system is considered. The generator is equipped with a PSS and the system has a STATCOM installed somewhere at point m in transmission line as shown in Fig. 1. The generator has a local load of admittance $Y_L = g + jb$ and the transmission line has impedances of $Z_1 = R_1 + jX_1$ and $Z_2 = R_2 + jX_2$ for the first and the second sections, respectively. The generator is represented by the third-order model comprising of the electromechanical swing equation and the generator internal voltage equation. The swing equation is divided into the following equations:

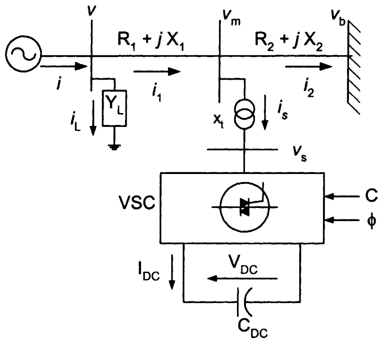

Fig. 1. Single machine infinite bus system with a STATCOM.

$$\dot{\delta} = \omega_b(\omega - 1) \tag{1}$$

$$\dot{\omega} = \frac{P_m - P_e - D(\omega - 1)}{M} \tag{2}$$

where P_m and P_e are the input and output powers of the generator, respectively; M and D the inertia constant and damping coefficient, respectively; ω_b the synchronous speed; δ and ω are the rotor angle and speed, respectively. The output power of the generator can be expressed in terms of the d- and q-axis components of the armature current, i, and terminal voltage, v, as

$$P_e = v_d i_d + v_q i_q \tag{3}$$

The internal voltage, E'_q, equation is

$$\dot{E}'_q = \frac{E_{fd} - (x_d - x'_d)i_d - E'_q}{T'_{do}} \tag{4}$$

where E_{fd} is the field voltage; T'_{do} the open circuit field time constant; x_d and x'_d are the d-axis reactance and the d-axis transient reactance of the generator, respectively.

2.2. Exciter

The IEEE Type-ST1 excitation system is considered in this work. It can be described as

$$\dot{E}_{fd} = \frac{K_A(V^{ref} - v) - E_{fd}}{T_A} \tag{5}$$

where K_A and T_A are the gain and time constant of the excitation system, respectively; V^{ref} is the reference voltage. The terminal voltage, v, can be expressed as

$$v = (v_d^2 + v_q^2)^{1/2} \tag{6}$$

$$v_d = x_q i_q \tag{7}$$

$$v_q = E'_q - x'_d i_d \tag{8}$$

where x_q is the q-axis reactance of the generator.

2.3. STATCOM-based stabilizers

As shown in Fig. 1, the STATCOM consists of a three-phase gate turn-off (GTO)-based voltage source converter (VSC) and a dc capacitor. The STATCOM model used in this study is found good enough for the low frequency oscillation stability problem [9–11]. The STATCOM is connected to the transmission line through a step-down transformer with a