Contents lists available at ScienceDirect

ISA Transactions

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

Research article

Model based PI power system stabilizer design for damping low frequency oscillations in power systems

Aprajita Salgotra*, Somnath Pan

Department of Electrical Engineering, Indian Institute of Technology (Indian School of Mines), Dhanbad 826004, India

A R T I C L E I N F O

Article history:
Received 7 December 2017
Received in revised form
22 February 2018
Accepted 18 March 2018
Available online xxx

Keywords:
Frequency response matching
Reference model
Direct synthesis
Low frequency oscillation
One machine infinite bus (OMIB) system
Proportional-integral power system stabilizer (PI-PSS)

A B S T R A C T

This paper explores a two-level control strategy by blending local controller with centralized controller for the low frequency oscillations in a power system. The proposed control scheme provides stabilization of local modes using a local controller and minimizes the effect of inter-connection of sub-systems performance through a centralized control. For designing the local controllers in the form of proportional-integral power system stabilizer (PI-PSS), a simple and straight forward frequency domain direct synthesis method is considered that works on use of a suitable reference model which is based on the desired requirements. Several examples both on one machine infinite bus and multi-machine systems taken from the literature are illustrated to show the efficacy of the proposed PI-PSS. The effective damping of the systems is found to be increased remarkably which is reflected in the time-responses; even unstable operation has been stabilized with improved damping after applying the proposed controller. The proposed controllers give remarkable improvement in damping the oscillations in all the illustrations considered here and as for example, the value of damping factor has been increased from 0.0217 to 0.666 in Example 1. The simulation results obtained by the proposed control strategy are favourably compared with some controllers prevalent in the literature.

© 2018 ISA. Published by Elsevier Ltd. All rights reserved.

1. Introduction

The low frequency oscillations in power systems had been noticeably observed in 1920s in the form of spontaneous oscillations and became more prominent when synchronous generators are interconnected to build-up more capacity. These oscillations are undesirable even at low frequencies (*i.e.* 0.1–2 Hz) as they reduce the power transfer capability of the transmission line [1]. The efforts to transfer bulk power across weak transmission line may lead to the low frequency oscillations [2]. It may be due to any disturbance such as sudden change in transmission line parameters or fluctuations in the turbine output power. In order to improve the transient stability, the gain is kept high for fast excitation that further aggravates the problem. To address this problem, a viable solution has been widely accepted by the power industries in the form of power system stabilizer (PSS). It adds a stabilizing signal to the excitation system to compensate the phase lag resulting from the voltage regulator, exciter and synchronous generator. In effect of this, the overall damping of the system is improved.

The two-level scheme has been observed in Ref. [3] where the overall system is decomposed into different sub-systems and an optimal controller is designed for each sub-system. This method involves tedious computation for obtaining the optimal gain of order n as $n(n+1)/2$ Riccatti equations are to be solved. Proportional-integral (PI) controllers (analog and digital) for one machine infinite bus (OMIB) and multi-machine systems have been designed in Ref. [4], however, interactions among the machines are not considered. Design of two-level PSS has been discussed in Ref. [5] where the effects of one machine over the other machines following a change in the mechanical torque in one or both the machines are simulated. A dynamic pole assignment technique has been proposed in Ref. [6] that uses pre-specified eigen-structure. In Ref. [7] a power system stabilizer is designed using the output feedback control based on the reduced-order model derived by the balanced truncation method. A two-level control strategy combined with order-reduction has been addressed in Ref. [8] to ensure fast convergence of the designed results. However, an approximate model matching technique for obtaining the parameters of PID controller may be observed in Ref. [9]. This technique may be applied without model-reduction, even for high-order systems. Moreover, model free control has been employed for differential

---

* Corresponding author.
E-mail address: aprajita.salgotra3@gmail.com (A. Salgotra).

https://doi.org/10.1016/j.isatra.2018.03.013
0019-0578/© 2018 ISA. Published by Elsevier Ltd. All rights reserved.

Please cite this article in press as: Salgotra A, Pan S, Model based PI power system stabilizer design for damping low frequency oscillations in power systems, ISA Transactions (2018), https://doi.org/10.1016/j.isatra.2018.03.013

Nomenclature

x_d, x_q	Direct and quadrature axis synchronous reactance, in order
x'_d	Direct axis transient reactance
x_e, r_e	Transmission line reactance and resistance, in order
v_d, i_d, ϕ_d	Direct axis voltage, current and flux linkage, in order
v_q, i_q, ϕ_q	Quadrature axis voltage, current and flux linkage, in order
i_{fd}	Field current
E'_q	Q-axis generator internal voltage
E_{FD}	Field voltage
V_∞, V_t	Infinite bus and terminal voltage, in order
ω	Angular velocity
K_A, T_A	Exciter gain and time constant, in order
T'_{d0}	Open-circuit generator field time constant
M	Inertia constant
D	Prime mover damping
T_m, T_e	Prime mover and Electrical torque, in order
θ	Angular position of direct axis w.r.t. stator
Δ	Small excursions about an initial operating point
δ	Angle between quadrature axis and infinite bus voltage
K_E, T_E	Exciter gain and time constant, in order
K_F, T_F	Regulating stabilizing circuit gain and time constant, in order
V_F	Stabilizing feedback signal of IEEE Type-DC1 excitation system

algebra based intelligent PID control in Ref. [10], time-delay estimation based intelligent PI control in Refs. [11,12], sliding mode control based PI control in Ref. [13]. In Ref. [14], a model matching approach is used to solve a H_∞ problem and the parameters are determined by closed-loop shaping. Recently, Yaghooti et al. [14] has designed a coordinated PSS using model reference adaptive technique. For multi-machine system, the mathematical modeling and block diagram showing the interactions among various subsystems has been explained elaborately in Ref. [15]. Among the efforts to address the low frequency oscillations problem, energy storage devices offer a viable solution to maintain the power system stability and its role has been elaborated in Ref. [16].

Apart from these methods, some authors have used the soft computing techniques that do not require a mathematical model of the system. These methods include the artificial intelligence techniques such as artificial neural networks [17], self-tuned fuzzy logic [18], bacteria foraging optimization [19] and the heuristic searching algorithm such as genetic algorithm [20], differential evolution [21], particle swarm optimization [22], harmony search algorithm [23], etc. These methods rely on iterative procedure and most of these techniques have high computation burden.

Furthermore, many methods prevalent in the literature require reduction of the system model to design the controllers. With all these in view, always there is a need for finding a simple method which will result in a simple but effective controller for operation and performance.

In this paper, a PI-PSS is proposed owing to its simplicity in structure, robustness, ease of implementation and maintenance. A suitable phase-lead may be obtained by employing a PI controller to compensate the phase-lag introduced between the exciter input and the electrical torque [4]. Here, the aim is to propose a design procedure that is simple in mathematics, less involved in computation and independent of order (without requiring system order reduction) and structure of the system. These objectives are achieved by blending two controllers, local and centralized — that results in effective achievement for the damping of the system. The local controller is designed using the concept of a method as in Ref. [9] which is involved in finding only two parameters of the PI controller against finding six parameters of the conventional lead-lag PSS. Unlike in Ref. [9], proposed method investigates in finding a suitable reference model considering oscillatory/unstable dynamics of the nominal system along with the consideration of desired response. This local controller ensures a minimum system performance even when the centralized controller becomes ineffective in the event of any contingency. The centralized controller is proposed to design using the method as in Refs. [5,8], for reduction of the interactions among the sub-systems. Examples are taken from the literature on one machine infinite bus (with IEEE type-DC1 and IEEE type-ST1 exciters) and multi-machine power systems.

The rest of the paper is organized as follows. The design methodology is shown in Section 2. In Section 3 simulation of four examples taken from the literature is illustrated. Finally, conclusion is drawn in Section 4.

2. Design methodology

The small perturbation based block diagram of the one machine infinite bus (OMIB) system with IEEE type DC excitation as shown in Fig. 1 is considered here [24] for design of the PI-PSS as the local controller.

2.1. Design of the local PI controller

The design method presented in Ref. [9] is followed here for design of the PI controller for mitigating the low frequency oscillations. The overall transfer function of the control system with the unknown controller has been derived analytically considering the mechanical torque deviation (ΔT_m) as input and the speed deviation $(\Delta\omega)$ as output as given by:

$$T_C(s) = \frac{G_3(s)[1+G_1(s)G_2(s)K_6(s)]}{\begin{array}{l}1+G_3(s)G_4(s)K_1-G_1(s)G_2(s)G_3(s)G_4(s)K_2K_5-G_2(s)G_3(s)G_4(s)K_2K_4\\ +G_1(s)G_2(s)K_6+G_1(s)G_2(s)G_3(s)K_2H(s)+G_1(s)G_2(s)G_3(s)G_4(s)K_1K_6\end{array}} \tag{1}$$

where, $H(s)$ is the controller to be designed. $G_A(s)$, $G_U(s)$ and $G_S(s)$ represents the transfer function of the AVR, the saturation compensation and the AVR stabilization circuit, respectively, while $G_1(s)$ consisting of all these three transfer functions represents the IEEE Type-DC1 exciter system [25].

Please cite this article in press as: Salgotra A, Pan S, Model based PI power system stabilizer design for damping low frequency oscillations in power systems, ISA Transactions (2018), https://doi.org/10.1016/j.isatra.2018.03.013

Download English Version:

https://daneshyari.com/en/article/7116167

Download Persian Version:

https://daneshyari.com/article/7116167

Daneshyari.com