Power System with PSS and FACTS Controller: Modelling, Simulation and Simultaneous Tuning Employing Genetic Algorithm

Sidhartha Panda and Narayana Prasad Padhy

***Abstract*—**This paper presents a systematic procedure for modelling and simulation of a power system installed with a power system stabilizer (PSS) and a flexible ac transmission system (FACTS)-based controller. For the design purpose, the model of example power system which is a single-machine infinite-bus power system installed with the proposed controllers is developed in MATLAB/SIMULINK. In the developed model synchronous generator is represented by model 1.1. which includes both the generator main field winding and the damper winding in q-axis so as to evaluate the impact of PSS and FACTS-based controller on power system stability. The model can be can be used for teaching the power system stability phenomena, and also for research works especially to develop generator controllers using advanced technologies. Further, to avoid adverse interactions, PSS and FACTS-based controller are simultaneously designed employing genetic algorithm (GA). The non-linear simulation results are presented for the example power system under various disturbance conditions to validate the effectiveness of the proposed modelling and simultaneous design approach.

***Keywords*—**Genetic algorithm, modelling and simulation, MATLAB/SIMULINK, power system stabilizer, thyristor controlled series compensator, simultaneous design, power system stability.

NOMENCLATURE

δ	Rotor angle of synchronous generator in radians
ω_B	Rotor speed deviation in rad/sec
S_m	Generator slip in p.u.
S_{mo}	Initial operating slip in p.u.
H	Inertia constant
D	Damping coefficient
T_m	Mechanical power input in p.u.
T_e	Electrical power output in p.u.
E_{fd}	Excitation system voltage in p.u.
T'_{do}	Open circuit d-axis time constant in sec
T'_{qo}	Open circuit q-axis time constant in sec
x_d	d-axis synchronous reactance in p.u.
x'_d	d-axis transient reactance in p.u.
x_q	q-axis synchronous reactance in p.u.
x'_q	q-axis transient reactance in p.u.
X_C	Nominal reactance of the fixed capacitor *C*
X_P	Inductive reactance of inductor *L* connected in parallel with *C*.
σ	Conduction angle of TCSC
α	Firing angle of TCSC
k	Compensation ratio, $k = \sqrt{X_C / X_P}$
V_t	Generator terminal voltage
E_b	Infinite-bus voltage
V_S	Stabilizing signal from power system stabilizer
T_W	Washout time constant

I. INTRODUCTION

WITH the advent of flexible ac transmission system (FACTS) devices [1], such as thyristor controlled series compensator (TCSC), static synchronous compensator (STATCOM) and unified power flow controller (UPFC), the unified model of single-machine infinite-bus (SMIB) power system installed with a TCSC, STATCOM and a UPFC have been developed [2]-[4]. These models are the popular tools amongst power engineers for studying the dynamic behaviour of synchronous generators, with a view to design control equipment. However, the model only takes into account the generator main field winding and the generator damping windings are not accounted for. Further, these liner methods cannot properly capture complex dynamics of the system,

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especially during major disturbances. This presents difficulties for designing the FACTS controllers in that, the controllers designed to provide desired performance at small signal condition do not guarantee acceptable performance in the event of major disturbances.

In [5], a systematic procedure for modeling, simulation and optimal tuning of TCSC controller in a SMIB power system was presented where the MATLAB/SIMULINK based model was developed and genetic algorithm (GA) was employed to design the TCSC controller. However, the model only takes into account the generator main field winding and the synchronous machine was represented by model 1.0. For more reasonable evaluation of a SMIB power system with FACTS controller, a higher-order synchronous machine model (model 1.1), which includes one damper winding along the q-axis, is reported in the literature [6]. As power system stabilizers (PSS) are now routinely used in the industry, this paper considers a SMIB power system installed with a PSS and a FACTS controller, where the synchronous machine is represented by a higher order model (model 1.1).

The problem of PSS parameter tuning in the presence of FACTS-based controller is a complex exercise, as uncoordinated local control of these controllers may cause destabilizing interactions. To improve overall system performance, many researches were done on the coordination between PSS and FACTS power oscillation damping (POD) controllers [7]-[9]. A number of conventional techniques have been reported in the literature pertaining to design problems of conventional power system stabilizers namely: the eigenvalue assignment, mathematical programming, gradient procedure for optimization and also the modern control theory. Unfortunately, the conventional techniques are time consuming as they are iterative and require heavy computation burden and slow convergence. In addition, the search process is susceptible to be trapped in local minima and the solution obtained may not be optimal [10].

GA is becoming popular for solving the optimization problems in different fields of application, mainly because of their robustness in finding an optimal solution and ability to provide a near-optimal solution close to a global minimum. Unlike strict mathematical methods, the GA does not require the condition that the variables in the optimization problem be continuous and different; it only requires that the problem to be solved can be computed. GA employs search procedures based on the mechanics of natural selection and survival of the fittest. The GAs, which use a multiple-point instead of a single-point search and work with the coded structure of variables instead of the actual variables, require only the objective function, thereby making searching for a global optimum simpler [11]. Therefore, in the present work GA is employed to simultaneously tune the parameters of PSS and FACTS controller.

This paper is organized as follows. In Section II, the modeling of power system under study, which is a SMIB power system with a PSS and a thyristor controlled series compensator (TCSC), is presented. The proposed controller structures and problem formulation are described in Section III. A short overview of GA is presented in Section IV. Simulation results are provided and discussed in Section V and conclusions are given in Section VI.

II. POWER SYSTEM UNDER STUDY

The SMIB power system with TCSC shown in Fig. 1 is considered in this study. The synchronous generator is delivering power to the infinite-bus through a double circuit transmission line and a TCSC. In Fig. 1, V_t and E_b are the generator terminal and infinite bus voltage respectively; X_T, X_L and X_{TH} represent the reactance of the transformer, transmission line per circuit and the Thevenin's impedance of the receiving end system respectively.

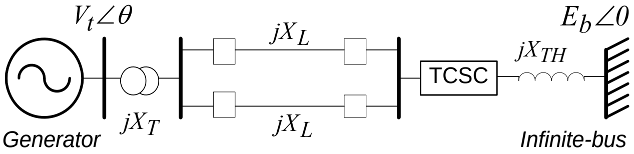

Fig. 1 Single-machine infinite-bus power system with TCSC

A. Modelling the Synchronous Generator Infinite-bus Power System

The synchronous generator is represented by model 1.1, i.e. with field circuit and one equivalent damper on q-axis. The machine equations are [12]:

$$\frac{d\delta}{dt} = \omega_B \left(S_m - S_{mo}\right) \tag{1}$$

$$\frac{dS_m}{dt} = \frac{1}{2H}\left[-D\left(S_m - S_{mo}\right) + T_m - T_e\right] \tag{2}$$

$$\frac{dE'_q}{dt} = \frac{1}{T'_{do}}\left[-E'_q + \left(x_d - x'_d\right) i_d + E_{fd}\right] \tag{3}$$

$$\frac{dE'_d}{dt} = \frac{1}{T'_{qo}}\left[-E'_d + \left(x_q - x'_q\right) i_q\right] \tag{4}$$

The electrical torque T_e is expressed in terms of variables E'_d, E'_q, i_d and i_q as:

$$Te = E'_d\, i_d + E'_q\, i_q + \left(x'_d - x'_q\right) i_d\, i_q \tag{5}$$

For a lossless network, the stator algebraic equations and the network equations are expressed as:

$$E'_q + x'_d\, i_d = v_q \tag{6}$$

$$E'_d - x'_q\, i_q = v_d \tag{7}$$

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