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Modelling of Single Machine Infinite Bus System

Abhishek Upadhyay, Arpit Kumar Gupta, Sukhveer Singh Yadav
Department of Electrical Engineering, Moradabad Institute of Technology, Moradabad, India

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Abstract

A power system at a given operating state and subjected to a given disturbance is voltage stable if the voltages near loads approach post-disturbance equilibrium values. by using the energy function that maps the energy variation of the system, the effect of the slow chance of the system is analyzed and thus the system's energy level changes that the stored energy measure is an indicator of the closeness of the operating point to the instability region of the system. With constraints on data availability and for study of power system stability it is adequate to model the synchronous generator with field circuit and one equivalent damper on q-axis known as the model 1.1. This paper presents a systematic procedure for modelling and simulation of a single-machine infinite-bus power system installed with a thyristor controlled series compensator (TCSC) where the synchronous generator is represented by model 1.1, so that impact of TCSC on power system stability can be more reasonably evaluated.

1. Introduction

Traditionally, for the small signal stability studies of a single-machine infinite-bus (SMIB) power system**,** the linear model of Phillips-Heffron has been used for years, providing reliable results. It has also been successfully used for designing and tuning the classical power system stabilizers (PSS). Although the model is a linear model, it is quite accurate for studying low frequency oscillations and stability of power systems. With the advent of Flexible AC controlled series compensator (TCSC), static synchronous compensator (STATCOM) and unified power flow controller (UPFC), the unified model of SMIB power system installed with a TCSC, STATCOM and a UPFC have been developed. 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 hence these models may not always yield a realistic dynamic assessment of the SMIB power system with FACTS because the generator damping winding in q-axis is not accounted for. Further, liner methods cannot properly capture complex dynamics of the system, especially during major disturbances. The electric power system stability has been considered as an important problem in terms of reliable system operation. The concept of voltage stability is expressed as the ability of keeping voltages' magnitudes of load buses, under both in steady state voltage stability and transient voltage stability conditions, within the specific operating limitations. In the cases of not making voltage control and increase the load due to disabling, for any reason, the elements such as generator, line, transformer, bus etc if an uncontrolled voltage drop occurs, then there appears power system instability. The main reason of the voltage instability is that in the overloaded systems the system can not ensure the reactive energy needed by the system to keep voltage values in a certain amount. Other reasons are generator reactive power limits, load characteristics, characteristics of load tap changer transformers, characteristics of reactive power compensation devices and behaviour of voltage control devices. Voltage stability and collapses began to play a significant role in power system analysis.

The deregulation and competitive environment in the contemporary power networks will imply a new scenario in terms of load and power flow condition and so causing problems of line transmission capability. it's tough to vary this structure of transmission system. So, the requirement for brand new power flow controllers capable of increasing transmission capacity and controlling power flows through predefined transmission corridors is increased. For this reason, as well known in recent

Corresponding Author,
E-mail address: upadhyayabhishek14@gmail.com

years a new class of controllers, Flexible AC Transmission System (FACTS) controllers have speedily met with favour. Indeed, the 2 main objectives of FACTS technology are to control power flow and increase the transmission capacity over an existing transmission line.

2. Power System under Study

The model of synchronous machine in SIMULINK and MATLAB. The system of study is the one machine connected to infinite bus system through a transmission line having resistance (re) and inductance (xe) shown in Figure 1. The generator is modeled by transient model, according to the following equations. All system data can be found in Appendix.

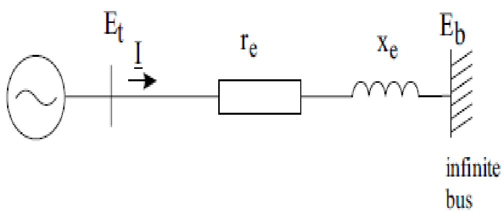


Figure 1: One machine to infinite bus system

2.1 Stator winding equations

$$v_q = -r_s i_q - x_d' i_d + E_q' \quad (1)$$

$$v_d = -r_s i_d + x_q' i_q + E_d' \quad (2)$$

Where
rs is the stator winding resistance
xd' is the d-axis transient resistance
xq' is the q-axis transient resistance
Eq' is the q-axis transient voltage
Ed' **is** the d-axis transient voltage
Rotor winding equations:

$$T_{do}' \frac{dE_q'}{dt} + E_q' = E_f - (x_d - x_d') i_d \quad (3)$$

$$T_{qo}' \frac{dE_d'}{dt} + E_d' = (x_q - x_q') i_q \quad (4)$$

Where
Tdo' is the d-axis open circuit transient time constant
Tqo' is the q-axis open circuit transient time constant
Ef is the field voltage

2.2 Torque equation:

$$T_{el} = E_q' iq + E_d' i_d + (x_q' - x_d') i_d i_q$$

2.3. Rotor equation

$$2H \frac{d\omega}{dt} = T_{mech} - T_{el} - T_{damp} \quad (6)$$

$$T_{damp} = D \Delta w \quad (7)$$

Where
T_{mech} is the mechanical torque, which is constant in this model
Tel is the electrical torque
T_{damp} is the damping torque
D is the damping coefficient.

These blocks represent the transformation of the synchronously rotating reference input value to the reference frame rotating with the rotor, and vice versa. The transformation matrices are:

$$T = \begin{bmatrix} \cos\delta & -\sin\delta \\ \sin\delta & \cos\delta \end{bmatrix} \quad \text{and} \quad T^{-1} = \begin{bmatrix} \cos\delta & \sin\delta \\ -\sin\delta & \cos\delta \end{bmatrix} \quad (8)$$

Where δ is the rotor angle?

The investigation of the behavior of the generator is done in two ways. In the first case the inputs are the infinite bus voltage, transformed into rotating frame, the field voltage and the mechanical torque, The machine terminal and infinite bus voltages in terms of the d and q components are

$$\tilde{E}_t = v_d + j v_q \quad (9)$$

$$\tilde{E}_b = E_{bd} + j E_{bq} \quad (10)$$

$$\tilde{E}_t = \tilde{E}_b + (r_e + j x_e) \quad (11)$$

$$(v_d + j v_q) = (E_{bd} + j E_{bq}) + (r_e + j x_e)(i_d + j i_q) \quad (12)$$

Resolving into d and q components gives

$$v_d = r_e i_d - x_e i_q + E_{bd} \quad (13)$$

$$v_d = r_e i_q + x_e i_d + E_{bq} \quad (14)$$

Where

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, $k=\sqrt{X_C/X_P}$

3. Problem Formulation

3.1 Structure of the TCSC Controller

The structure of TCSC-based damping controller, to modulate the reactance offered by the TCSC, X_{TCSC} (α) is shown in fig: 2 The input signal of the proposed controllers is the speed deviation ($\Delta\omega$), and the output signal is the reactance offered by the TCSC, X_{TCSC} (α). The structure consists of a gain block with gain K_T, a signal washout block and two-stage phase compensation blocks. The signal washout block serves as a high-pass filter, with the time constant T_{WT}, high enough to allow signals associated with oscillations in input signal to pass unchanged.

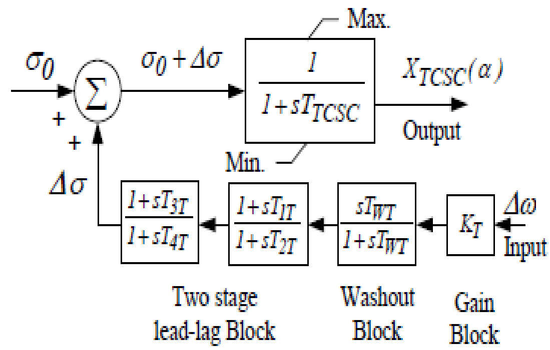


Fig: 2. Structure of TCSC-based controller

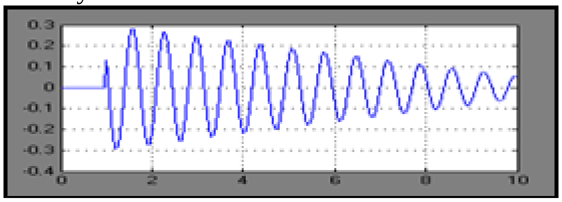
3.2 Problem Formulation

In the present study, a washout time constant of T_{WT} =10s is used. The controller gain K_T and the time constants T_{1T}, T_{2T}, $T3T$ and T_{4T} are to be determined. During steady state conditions $\Delta\sigma$ and $\sigma\ 0$ are constant. During dynamic conditions, conduction angle (σ) and hence $X_{TCSC\,(\alpha)}$ is modulated to improve power system stability. The desired value of compensation is obtained through the change in the conduction angle ($\Delta\sigma$), according to the variation in $\Delta\omega$. The effective conduction angle σ during dynamic conditions is given by:

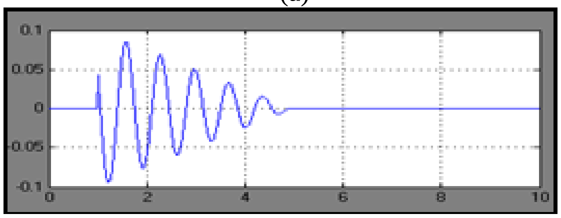
$$\sigma = \sigma_0 + \Delta_\sigma$$

3.3 Output feed back

The feature of a sliding mode control system is that the controller is switched between distinctive control structures and the system trajectory is forced to reach the sliding surface and to slip on it. Once the states of the system enter the sliding mode,the dynamics of the system are determined by the selection of sliding surface and are independent of uncertainties and disturbances. As a result, the sliding mode control is a robust control method and it has found broad applications. Considering the sliding mode control with multirate feedback, some studies and analysis were undertaken. In real management applications, totally different management signal rates and device output rates area unit typically used. Such type of system is called as multirate system. The continuous time sliding mode controller is robust to disturbances but the discrete-time controller is sensitive to output measuring error, as a result of a shift perform is enclosed within the controller. The state of the sliding mode controller is complete by combining the use of multirate output feedback and past plant outputs, then the management gains embrace extra style parameters. As a result, management performance is improved. The multirate output feedback also guarantees closed loop system stability.



(a)



(b)

Fig:-3 Rotor Angle Stability (a) WITHOUT UPFC & (B) WITH UPFC

4. Simulation Results

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The UPFC model is implemented using MATLAB software. The UPFC model is located at the sending end of the transmission line and is controlled in such a way to follow the changes in reference values of the line active and reactive power, and the reactive power of its shunt inverter. Proposed UPFC model is designed using Multirate. Sliding Mode Control technique .Robustness of this technique enhances transient stability of the system. The design of control system is considered to discrete time system.

5. Conclusion

An UPFC model with PSS design scheme using multirate output feedback sliding mode control technique has been proposed in this paper. The proposed scheme provides good damping enhancement and increases transient stability for single machine infinite bus system. Proposed model can be extended for multi-machine bus system for providing good damping to electromechanical oscillations in power system.

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Appendix

The generator parameters in per unit are as follows:
Xd = 1:79 Xq = 1:66 X'd = 0:355 X'q = 0:57
Rs = 0:0048
T'd0 = 7:9s T'q0 = 0:41s H = 3:77 Dw = 2
Tmech = 0:8s
The exciter parameters in per unit are as follows:
KA = 50 TA = 0:06s TE = 0:052s KE = -0:0465
TF = 1:0s KF = 0:0832 AE = 0:0012 BE = 1:264
VmaxR = 1 VminR = -1
The external line parameters are: re = 0:2
xe = 0