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Study of Transient Stability with Static Synchronous Series Compensator for an SMIB

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Abstract - ***The MATLAB model of a single-machine infinite-bus power system with a SSSC controller presented in the paper provides a means for carrying out transient system stability analysis and for explaining the generator dynamic behavior as affected by a SSSC. This model is far more realistic compared to the model available in open literature, since the synchronous generator with field circuit and one equivalent damper on q-axis is considered. The controller is tested on example power system subjected to various large and small disturbances. The MATLAB results show that, the genetically tuned SSSC controller improves the stability performance of the power system and power system oscillations are effectively damped out***

Key Words: *SSSC, Transient Stability.*

1. Introduction

The importance of power system stability is increasingly becoming one of the most limiting factors for system performance. Recent major black-outs across the globe caused by system instability, even in very sophisticated and secure systems, illustrate the problems facing secure operation of power systems. With increase automation and use of electronic equipment, the quality of power has gained utmost importance, shifting focus on the concepts of voltage stability, frequency stability, inter-area oscillations etc. By the stability of a power system, we mean the ability of a system to remain in operating equilibrium, or synchronism, while disturbances occur on the system

Transient stability of power systems becomes a major factor in planning and day-to-day operations and there is a need for fast on-line solution of transient stability to predict any possible loss of synchronism and to take the necessary measures to restore stability. Recently various controller devices are designed to damp these oscillations and to improve the system stability, which are found in modern power systems, but Static Series Synchronous compensator (SSSC) still remains an attractive solution.

2. System Modelling

The models of the major components of the power system that determines its dynamic behavior are discussed in this chapter. For the present project work a SMIB (single machine connected to an infinite bus) system is undertaken. This system can be considered for study because it can represent a complex interconnected network if the rest of the system is presented by the Thevenin's equivalent. Study of such a simplified system can also predict the behavior of complex interconnected network. The system connected is a two port network, in which one of port is connected to the generator terminals while the second port is connected to a voltage source ($E_b\angle 0$), whose magnitude and phase angle does not change with time, so it is called the infinite bus.

3. TRANSIENT STABILITY ANALYSIS

A typical transient stability study consists of obtaining the time solution to the power system differential and algebraic equations starting with the system conditions prior to the transient. The power system equations should include all significant parameters that influence stability such as generator controls, stability controls and protective devices.

i. The stability of the power system. Is it stable or not, to what degree is it stable, and how far is

it from the stability limits?

ii. Time responses of generator variables, bus voltages, currents, and active and reactive power.

iii. System quantities that affect the performance of protective devices.

In contrast to this disturbance-specific transient instability, there exists another class of instability called the 'dynamic instability' or more precisely 'small oscillation instability'. As the small oscillation stability concerns itself with small excursions of the system about a quiescent operating point, the system can be sometimes approximated by a 'linearized model' about the particular operating point. Once valid linearized model is available, powerful and well established techniques of the linear control theory can be applied for stability analysis and performance evaluation of various power system stabilizers.

Nonlinear models on the other hand have more realistic representation of the power systems. Designing controllers for such nonlinear systems are understandably more difficult. In this chapter, nonlinear models of single machine infinite bus system have been developed. Linear models have been obtained from these nonlinear models for designing conventional power system stabilizers that are used for comparative performance analysis.

Here we are using only state equations to obtain transient stability. There are changes in system parameters due injection of controller voltage

4. SSSC controller

Transient stability analysis of a Single Machine Infinite Bus (SMIB) with fixed capacitor alone in the network, disturbances damp out slowly. The system with fixed capacitor becomes unstable after application of disturbance, using of SSSC controller to overcome instability after application of disturbance discussed in next chapter.

the system with SSSC controller without application of disturbance is more stable when compared to fixed capacitor alone. After some time instance almost all parameters i.e. slip, delta, etc came to stable. it is observed that it took less time to come to stable when compared the fixed capacitor.

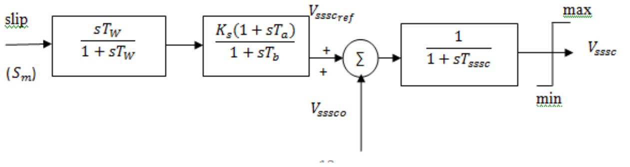
The disturbance is created by changing the reactance of the network at various instances and observes the transient stability at various values of x_e at some time instance t>0.5 and t<0.9

The system is instable at disturbance given. Disturbance is increased with x_e=0.17, but after some time instance the system becomes stable.stability is calculated for different values of x_e.

When the SSSC is present in the network then the network equations are modified, because the voltage introduced in the line may be fixed or variable, but the phase angle of the injected voltage at any instant of time should be at an angle of 90^0 to the line current flowing at that instant. Therefore modifying the earlier network equation, the new equations applicable for network is given below

$$V_q = R_e I_q - x_e I_d + h_1 E_b \cos\delta + h_2 E_b \sin\delta - V_{sssc} \cos\beta$$

$$V_d = x_e I_q + R_e I_d + h_2 E_b \cos\delta - h_1 E_b \sin\delta - V_{sssc} \sin\beta$$



SSSC controller block diagram

The system with SSSC controller without application of disturbance is more stable when compared to fixed capacitor alone. After some time instance almost all parameters i.e. slip, delta, etc came to stable. it is observed that it took less time to come to stable when compared the fixed capacitor.

After giving disturbance of x_e=0.0, the system loses its stability and again came to stable condition after some time instance. The system is instable at that disturbance given.

Here, we give various disturbance to observe working function of SSSC controller even after at various disturbance and its stability properties to protect the system. we applied disturbance at x_e=0.0, but now we will just increase x_e value and observes the system parameters.

The system is instable at disturbance given. Disturbance is increased with x_e=0.17, but after some time instance the system becomes stable. Now apply disturbance at x_e next value to observe its Transient stability. the results of these disturbances are given below in figures.

Abbreviations and Acronyms

SSSC	: Static Series Synchronous Compensator
AVR	: Automatic Voltage Regulator
SMIB	: Single Machine Infinite Bus System

Equations

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

$$\frac{dS_m}{dt} = \frac{(-D(S_m - S_{mo}) + T_m - T_e)}{2H}$$

$$\frac{dE_q^{'}}{dt} = \frac{1}{T_{d0}^{'}}\left[-E_q^{'} + (x_d - x_d^{'})i_d + E_{fd}\right]$$

$$\frac{dE_d^{'}}{dt} = \frac{1}{T_{q0}^{'}}\left[-E_d^{'} - (x_q - x_q^{'})i_q\right]$$

$$\frac{dE_{fd}}{dt} = \frac{1}{T_A}\left[-E_{fd} + K_A(V_{ref} - V_g + V_s)\right]$$

$$\frac{dx_1}{dt} = -{}^{x_1}/_{T_w} + {}^{S_m}/_{T_w}$$

$$\frac{dV_{sssc}}{dt} = \frac{-V_{sssc} + V_{sssc_{ref}}}{T_{sssc}}$$

Plots are drawn between system parameter versus time.

FIGURES

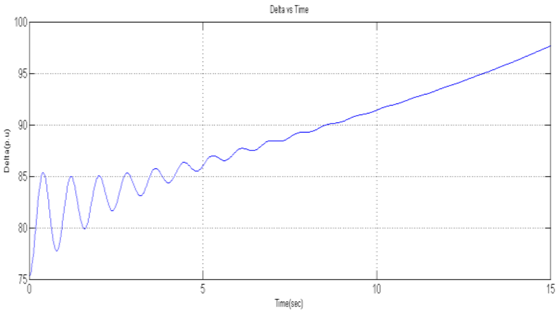


Fig-1: Rotor angle versus time with fixed capacitor

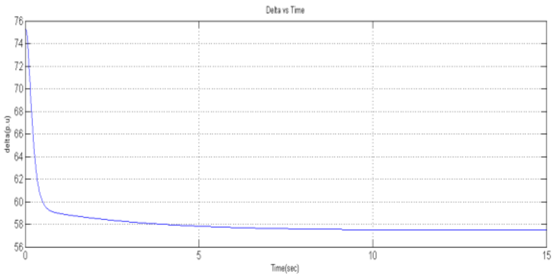


Fig-2: Rotor angle versus time without disturbance using SSSC controller

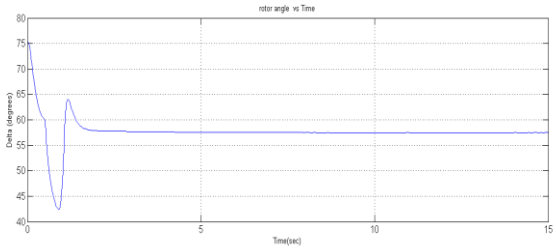


Fig-3: Rotor angle versus Time with disturbance using SSS controller

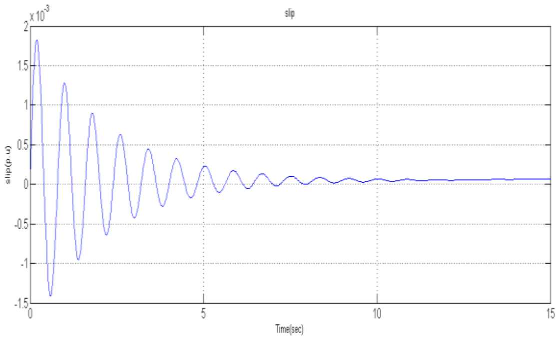


Fig-4: Slip versus time with fixed capacitor

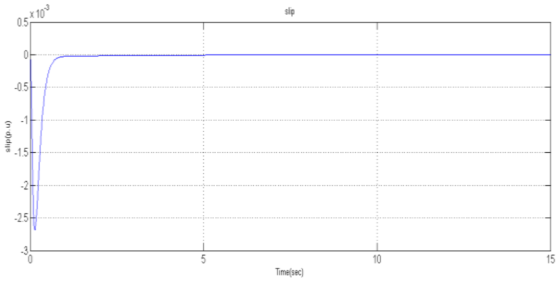


Fig-5: Slip versus time witout disturbance

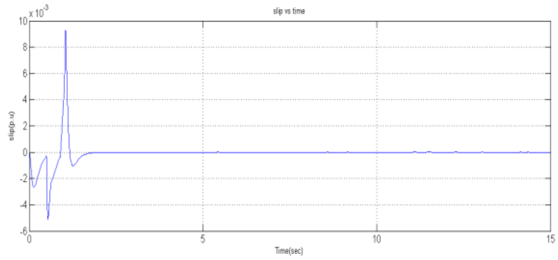


Fig-6: Slip versus time with disturbance

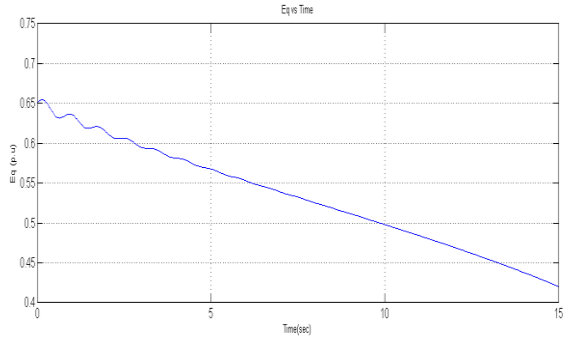


Fig-7: E_q versus time with fixed capacitor

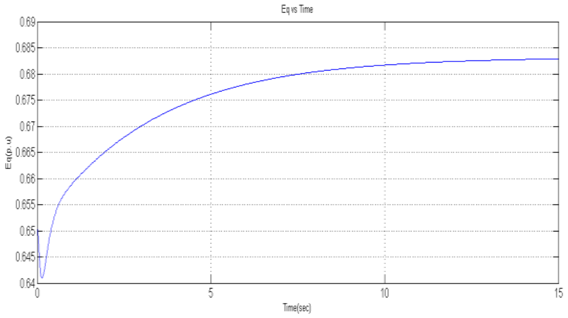


Fig-8: E_q versus time without disturbance using SSSC controller

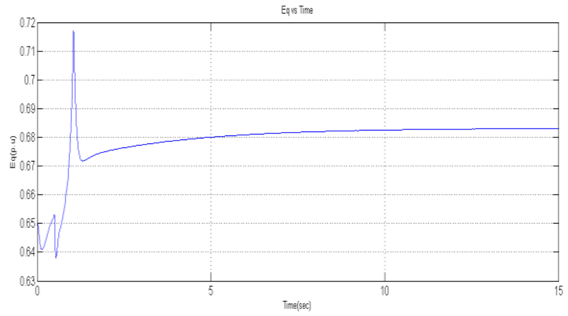


Fig-9: E_q versus time without disturbance using SSSC controller

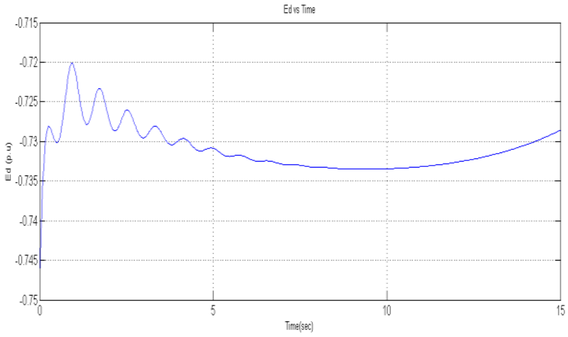


Fig-10: E_d versus time with fixed capacitor

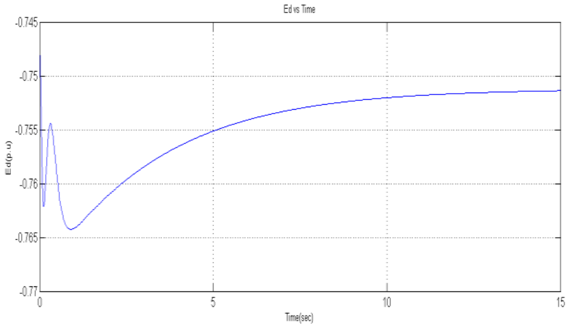


Fig-11: E_d versus time without disturbances with SSSC controller

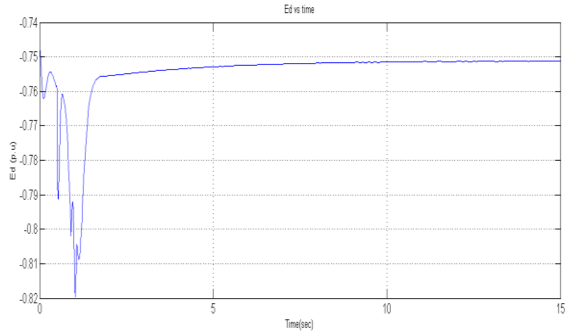


Fig-12: E_d versus time with disturbances with SSSC controller

4. Conclusion

Transient stability analysis of a Single Machine Infinite Bus(SMIB) with SSSC controller in the network. This device can also be used in presence of capacitor. The system will become unstable after application of disturbance at various instances and the system is stable after the adding the controller to the circuit. When disturbance created by giving various x_e the system is unstable for particular instance of time at which the disturbance is created. Using the SSSC controller the system is stable.

The MATLAB results show that, the genetically tuned SSSC controller improves the stability performance of the power system and power system oscillations are effectively damped out. Hence, it is concluded that the proposed model is suitable for carrying out power system stability studies in cases where the dynamic interactions of a synchronous generator and a SSSC are the main concern.

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