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Improvement of Dynamic Electrical Power System Stability Using Riccati Matrix Method

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Abstract. Power system stability means the ability to develop restoring forces equal to or greater than the disturbing forces to maintain the state of equilibrium. Successful operation of a power system depends largely on providing reliable and uninterrupted service to the loads by the power utility. The stability of the power system is concerned with the behavior of the synchronous machines after they have been disturbed. If the disturbance does not involve any net change in power, the machines should return to their original state. Due to small disturbances, power system experience these poorly damped low frequency oscillations. The dynamic stability of power systems are also affected by these low frequency oscillations. This paper presents to analyze and obtain the optimum gain for damping oscillation in SMIB by using Riccati matrix method to improve dynamic power system stability. The result shows that with suitable gain which is act as a stabilizer that taken from Riccati matrix, the oscillations of rotor speed and rotor angle can be well damped and hence the system stability is enhanced.

Introduction

Power system stability can be categorized into three types which are transient, steady state and dynamic. The differences between three types of electrical power system stability are referred to the size and effect of disturbance to the system. Transient stability and steady state stability are involves the study of the power system following a major disturbance while small-signal stability (also called dynamic stability) analysis studies the behavior of power systems under small perturbations[1]. Small-signal stability or the dynamic stability is usually concerned as a problem of insufficient or poorly damping of rotor oscillations or low-frequency oscillation (LFO). These oscillations are undesirable even at low-frequencies, because they reduce the power transfer in the transmission line and sometimes introduce stress in the system. Stability assessment of these low frequency oscillations is a vital concern and essential for secure power system operation and control. The stability of synchronous machine under small perturbation is explored by examining the case of a single machine to an infinite bus (SMIB).The model is based on state space variable equation. Power system without stabilizer can't be stable when a disturbance occurs. Riccati matrix method are designed to help in stability analysis and solve other control issue such as optimal control synthesis and model reduction[2]. This method is used by most of the researchers to solve the stability problems with additional devices and combination techniques. However, no studies are trying to simulate and prove the effectiveness of Riccati method in determining the optimum gain which is act as a stabilizer in the power system without any additional or combination technique.

Research Methodology

The stability of synchronous machine under small perturbation is explored by examining the case of a single machine to an infinite bus (SMIB) as shown in Fig. 1, G is synchronous machine, R_e and jX_e

are equivalent of resistance and reactance, respectively, V_t is terminal voltage and V_∞ is infinite bus voltage.

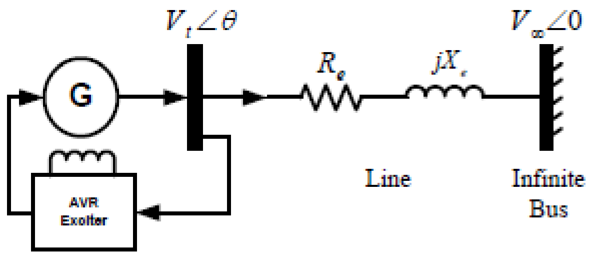

Fig. 1 A synchronous machine infinite bus

The synchronous machine infinite bus is stated in a state variable equation [3]:

$$\begin{bmatrix} \Delta\dot{\delta} \\ \Delta\dot{v} \\ \Delta\dot{E}'_q \\ \Delta\dot{E}_{fd} \end{bmatrix} = \begin{bmatrix} 0 & \omega_s & 0 & 0 \\ \frac{-K_1}{2H} & \frac{-D\omega_s}{2H} & \frac{-K_2}{2H} & 0 \\ \frac{-K_4}{T'_{do}} & 0 & \frac{-1}{K_3 T'_{do}} & \frac{1}{T'_{do}} \\ -\frac{K_A K_5}{T_A} & 0 & -\frac{K_A K_6}{T_A} & -\frac{1}{T_A} \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta v \\ \Delta E'_q \\ \Delta E_{fd} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{K_A}{T_A} \end{bmatrix} \Delta V_{ref}$$

The parameters of the studied SMIB power system are taken from [4]. It consists of common system parameters, generator, voltage regulator-excitation system, transmission line, and nominal operating point. Riccati matrix method is implemented to obtain the optimum gain of parameters which is fast and efficient. The optimum gain will be act as a stabilizer of the system which is will be calculated and applied into the SMIB by using MATLAB Simulink. The optimum gains will help to stabilize the damping oscillation in dynamic power system efficiently especially for rotor speed and rotor angle. Once the system is developed, it will simulated and shows in real the damping oscillation of the speed and angle can improve the damping system which is important in dynamic power system. In this stability study,the electrical power system can be known either taking a long time to be stable or not by comparing the result of speed and angle for before and after apply the disturbance.

The methodology of this research is summarized in a flow chart as shown in Fig. 2

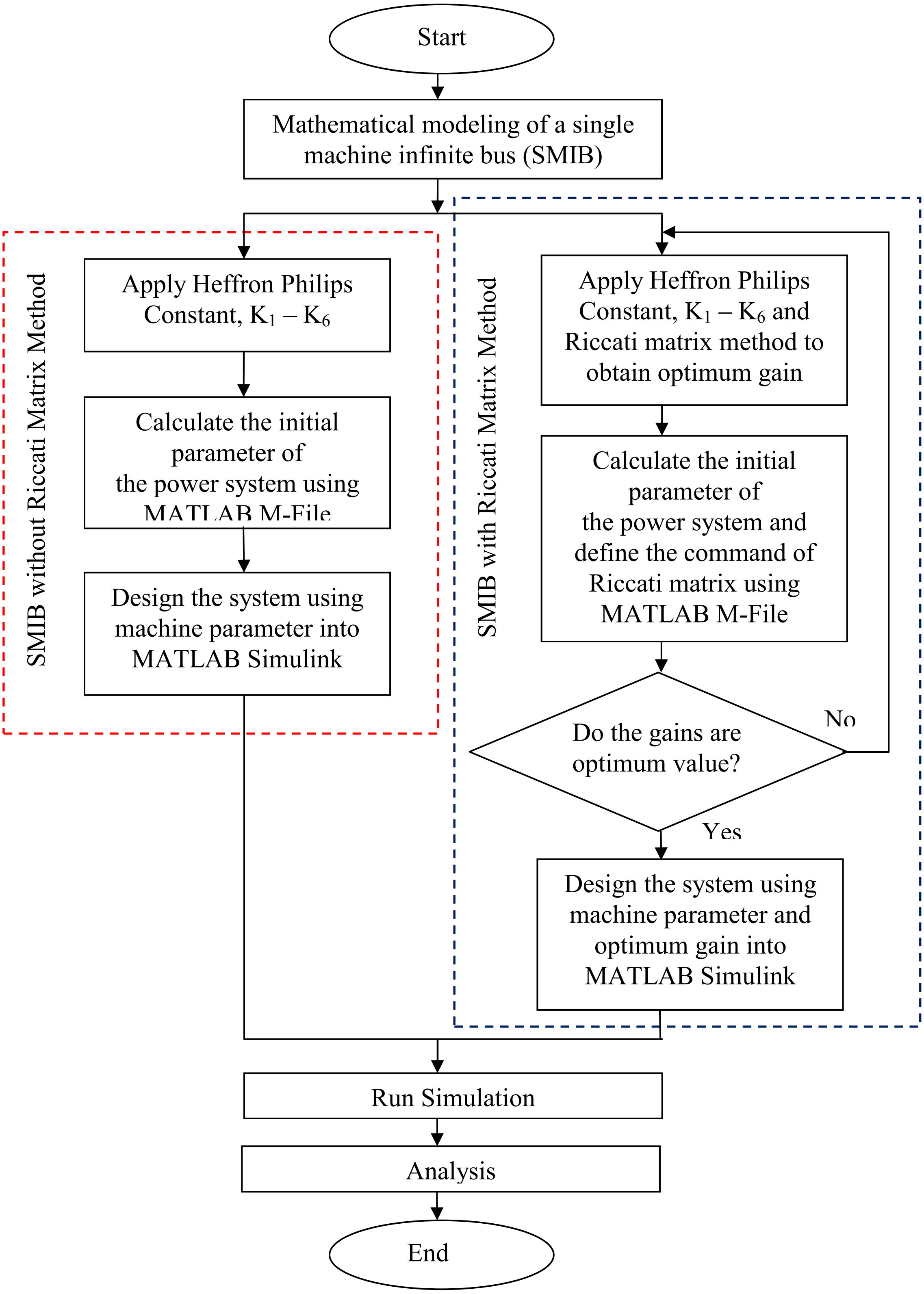

Fig. 2 Flow chart of the research

Result and Discussion

Fig. 3 and 4 shows the condition of rotor speed and rotor angle before apply Riccati matrix. All the parameters needed have been defined by using MATLAB M-File format. The optimum gains resulted by Riccati matrix are 1.7005,-13.0500, 4.1244 and 0.9809. Fig. 3 shows the rotor speed with small perturbation applied to the system. When 0.1p.u disturbance is applied, the peak time,T_p which is the time required to reach the first (maximum) peak is 1.1753s which is the overshoot reach 0.6939p.u. The time required for the oscillations to die down and stay within 2% of the final value (settling time) takes a long time to become a steady state. Fig.4 shows the rotor angle which is applied the same disturbance value and takes 1.3422s, overshoot time at 0.1862p.u.The time to system goes to steady state condition is longer than 15 sec.

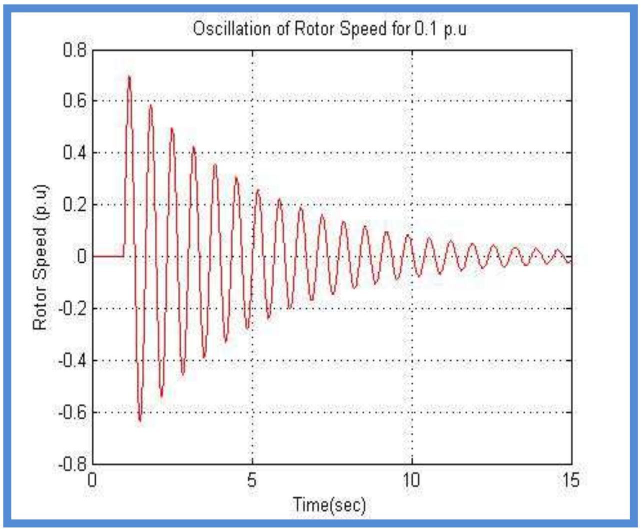

Fig. 3 Oscillation of rotor speed

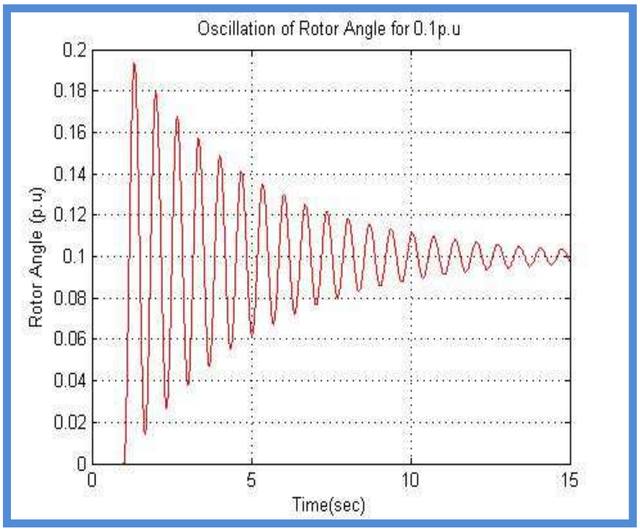

Fig. 4 Oscillation of rotor angle

Fig. 5 shows the different between before and after applies the Riccati matrix for rotor speed. After 0.1 p.u disturbance is applied, during 1.1788s SMIB with Riccati matrix has a same of overshoot value which is 0.6939p.u.The value is near to 0p.u which is the value for the system in equilibrium state. Fig.6 shows the different between before and after apply the Riccati method for rotor angle. It is become a steady state at 15s after 0.1p.u disturbance applied which is the value is 0p.u.

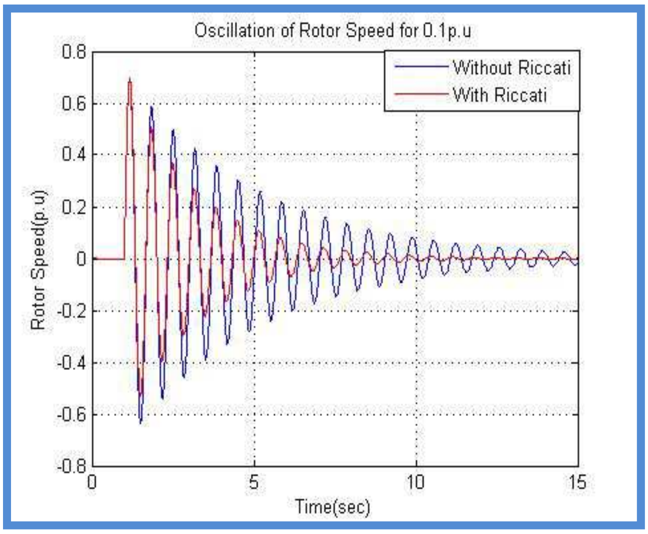

Fig. 5 Oscillation of rotor speed for both SMIB

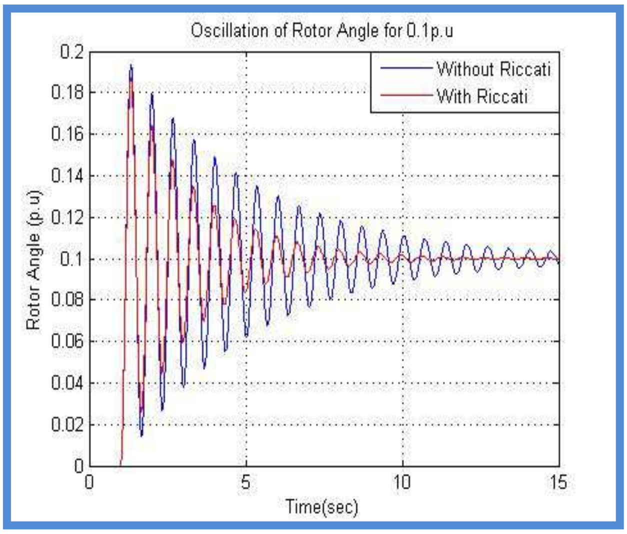

Fig. 6 Oscillation of rotor angle for both system SMIB system

Table 1: Oscillation of SMIB with and without Riccati matrix

	Oscillation			
	Rotor Speed (p.u)		Rotor Angle (p.u)	
	With Riccati	Without Riccati	With Riccati	Without Riccati
Damping Ratio, ς	0.0366	0.0145	0.0366	0.0145
Overshoot (p.u)	0.6939	0.6939	0.1862	0.1927
The value at 15sec (p.u)	0	-0.0255	0.1	0.0950
Peak Time, T_p (sec)	1.1788		1.3422	

Based on the results show in Table 1, the dynamic power system of SMIB with Riccati matrix is faster to achieve a steady state condition compare with the system without Riccati matrix which is takes time to reach steady state condition. The stability of the dynamic power system is measured by looking at the ability of the rotor speed and rotor angle to reach a steady state values which are 0p.u The optimum gains that get from Riccati matrix was help the system to get the well damped and can improve their time to achieve a steady state condition. The oscillation value during 15sec shows that a SMIB without Riccati matrix has a high value compared to with Riccati matrix. That's mean the time taken to go to the steady state is more than 15 sec. Same with the rotor angle which is the system needs more than 15 sec to reach the steady state. By looking at SMIB with Riccati matrix, the rotor speed and rotor angle have a value that near to the steady state value. That's mean the time taken to stabilize the overall system is shorter than without Riccati matrix. This is can conclude that Riccati matrix can help to improve the stability of dynamic power system faster than a SMIB without Riccati matrix.

Conclusion

The results for this research are getting from MATLAB Simulink. The optimum gains needed in the power system are taken from Riccati matrix method. The damping oscillation results between SMIB with and without applying Riccati matrix are also proved that Riccati matrix has the ability to increase the value of damping ratio which is help the system to oscillate faster than the original system. The higher of damping ratio means the faster of the system to decay the oscillation towards equilibrium state. A lower values of overshoot, settling time and peak time that obtained from SMIB with Riccati matrix are also show that the Riccati matrix was help to improve the stability of dynamic power system. This is because the stability of the power system is not only depends on the ability to reestablish the initial state but it is also related with the time taken by the system to go to the equilibrium state after being subjected. As a conclusion for this research based on the result of SMIB with and without Riccati matrix, the stability of the dynamic power system was improved by using Riccati matrix method.

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