The Robust control strategy for fast response of a synchronous generator excitation system

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ABSTRACT- This paper deals with the design and evaluation of the robust controller for a synchronous generator excitation system to improve the steady state and transient stability. The nonlinear characteristics of the system is treated as model uncertainties, and then the robust control techniques are introduced into the power system stability design to take into account these uncertainties at the controller design stage.

The performance of the designed controller is examined by extensive non-linear time domain simulation. It is shown that the performance of the robust controller is superior to that of the conventional PI controller.

1. INTROUCTION

A synchronous generator is equipped with an Automatic Voltage Regulator (AVR) , which is responsible for keeping the generator output voltage constant under normal operating conditions at various load levels.

The problem of power system dynamic stability has received growing attention over the past three decades. The main reasons for this are the increasing size of generating units an the use of high-speed excitaion systems. The effect of the high-speed excitaion on dynamic stability may cause steady state instability. Thereby, it is to add negative *damping causing* oscillations with weak damping.[1]

In pracice field, it has relied on the lead-lag compensators of the classic control.[2]The LQ(Linear Quadradic) contol theory has been used by many researchers to design PSS.[2,3] Even through the nominal performance of LQ PSS is quite satisfactory, its robust stability and robust performance are shown to be poor.[3] Much efforts have been studied to the controller design of relervant PSS, which have been used root locus, eigenvalue techniques[4], pole placement[5], adaptive control[6], etc. But in all these methods model uncertainties cannot be considered at the controller. Recently, the robust control has applied to the power system stabilizer design, which take consider the model uncertainties.[7,8]

This paper deals with the design and evaluation of the robust controller for a synchronous generator excitation system to improve the steady state and transient stability. The performance of the designed controller is examined by extensive non-linear time domain simulation. It is shown that the performance of the robust controller is superior to that of the conventional PI controller.

2. SYSTEM MODELING

The conventional PSS system is models as a synchronous generator connnected to an infinite bus through two parallel transmission, as shown in Fig.1.

In general, it is PSS(power system stabilizer) equipment using lead-lag compensator.

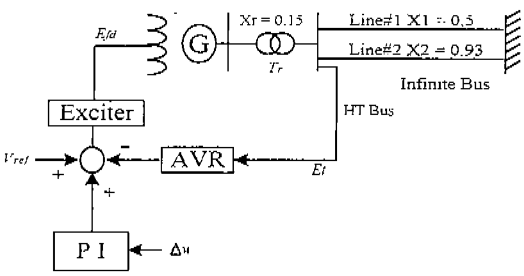


Fig 1. System configuration using the conventional PI control.

The robust control PSS system is models as a synchronous generator connnected to an infinite bus through two parallel transmission, as shown in Fig.2.

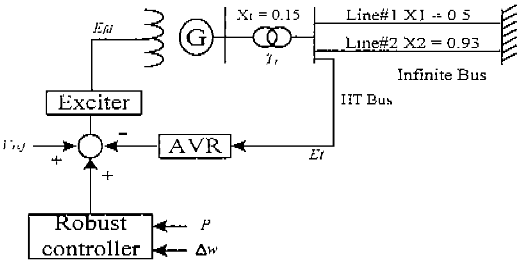
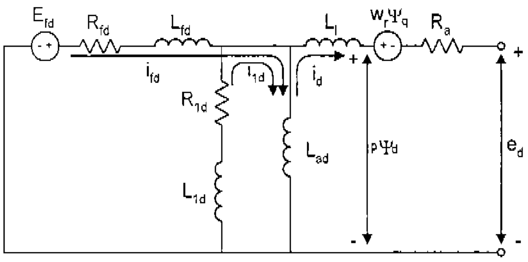
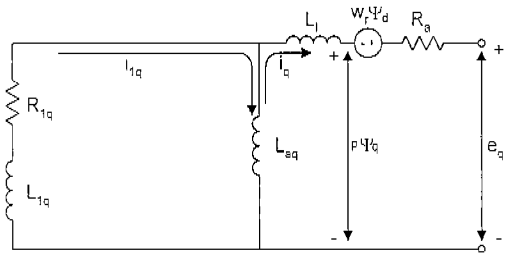


Fig. 2 System configuration using robust control.



(a) D-axis



(b) Q-axis

Fig. 3. D-Q axis equivalent circuit of a synchronous generator

The generator with arortisseurs is modeled as 6th order non-linear differential equations.

Stator voltage equations:

$$e_d = p\Psi_d - \Psi_q \cdot \omega_r - R_a \cdot i_a \tag{1}$$

$$e_q = p\Psi_q + \Psi_d \cdot \omega_r - R_a \cdot i_q \tag{2}$$

$$e_0 = p\Psi_0 - R_a \cdot i_0 \tag{3}$$

Rotor voltage equtions:

$$e_{fd} = p\Psi_{fd} + R_{fd} \cdot i_{fa} \tag{4}$$

$$0 = p\Psi_{1d} + R_{1d} \cdot i_{1a} \tag{5}$$

$$0 = p\Psi_{1q} + R_{1q} \cdot i_{1q} \tag{6}$$

$$0 = p\Psi_{2q} + R_{2q} \cdot i_{2q} \tag{7}$$

3. ROBUST CONTROL THEORY

Robust control theory deals with control system design for dynamic systems with uncertainties in their models. A controller is said to be robust to a given set of system uncertainties if it provides stability and satisfactory performance for all system models in this set.

In power system,the main source of model uncertainties is due to the change in operating conditiuons. Uncertainties are usually represented in terms of a bound on magnitude of the frequency response of the nominal system. The relationship can be shown as:

$$G(s) = (I + \triangle_m(s))G_o(s) \tag{8}$$

where $\triangle_m(s)$ is the multiplicative uncertainty bound.

This relationship is showns in Fig.4 with appropriate weighting functions W_1 & W_3.

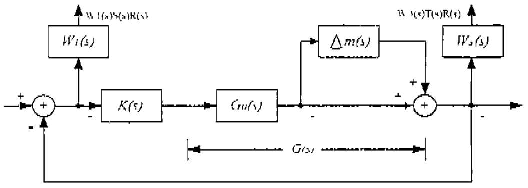


Fig.4 Uncertainty model and the weighted sensitivity functions

After considering these factors carefully, the weighting functions are selected as follows.

$$W_1(s) = \left[2.9\frac{s^2+s+1}{s+4}, 4.5\frac{s^2+s+1}{s+4}\right] \qquad (9)$$

$$W_3(s) = \left[\frac{1.0}{0.03}\frac{s+10}{s^2+s+1}, \frac{0.9}{0.03}\frac{s+10}{s^2+s+1}\right] \qquad (10)$$

4. SIMULATION RESULT

The performance of the designed controller is examined by extensive non-linear time domain simulation. The simulation results have indicated that the robust controller can maintain th system stability under all operating conditions and can provide greater damping than the conventional PI controller.

In Fig.5, a fault at high transimission is simulated. It is shown that the robust controller provides greater damping than the PSS.

5. CONCLUSION

This paper deals with the design and evaluation of the robust controller for a synchronous generator excitation system to improve the steady state and transient stability. The nonlinear characteristics of the system is treated as model uncertainties, and then the robust control techniques are introduced into the power system stability design to take into account these uncertainties at the controller design stage. The performance of the designed controller is examined by extensive non-linear time domain simulation. It is shown that the performance of the robust controller is superior to that of the conventional PI controller.

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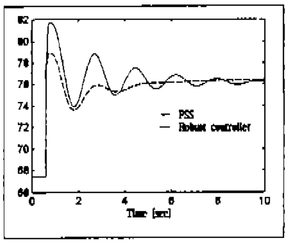
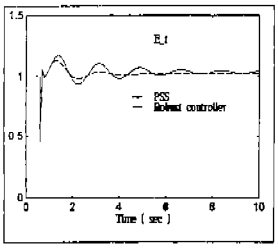
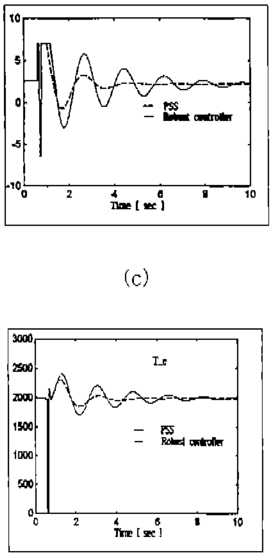


(a)



(b)



(c)

(d)

Fig.5 The Robust control & conventional PSS
(a)Electrical angle degree (b) Terminal voltage
(c)Exciter terminal voltage (d)Electrical power