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발전기 여자시스템의 속응성 제어기법

(The Control Strategy For Fast Response Of A Synchronous Generator Excitation System)

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요 약

본 논문은 동기 발전기 시스템의 정상상태와 과도상태 안정도를 개선하기 위해서 강인제어기를 설계하고 증명하였다 시스템의 비선형특성은 모델 불확실성으로 다루었고, 강인제어 기법은 제어기 설계에서 이 불확실성을 고려하여 전력시스템의 안정도 설계에 적용하였다. 디자인된 제어기의 특성은 비선형시간영역 시뮬레이션으로 확대하여 검토하였다. 강인제어기의 특성이 고전적인 PI 제어기보다 약20%정도 우수함을 보였다.

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 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 practice field, it has relied on the lead-lag compensators of the classic control.[2] The LQ(Linear Quadratic) contol theory has been used by many researchers to design PSS.[2,3] Even though 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 relevant PSS, which have been used root locus, eigenvalue techniques[4], pole placement[5], adaptive control[6], etc. But in all these methods

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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]

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.

2. SYSTEM MODELING

The conventional PSS system is models as a synchronous generator connected 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.

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.

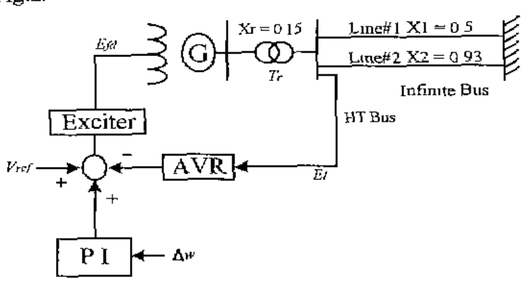


Fig. 1. System configuration using the conventional PI control.

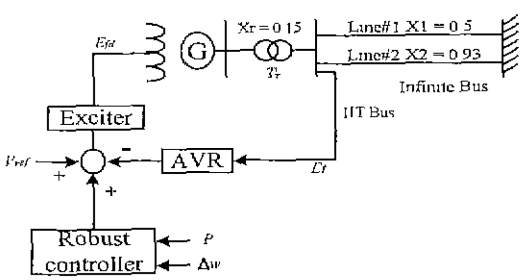


Fig. 2. System configuration using robust control.

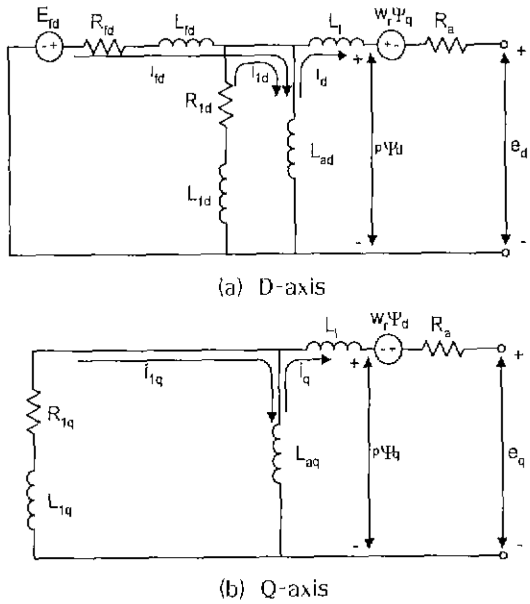


Fig. 3. D-Q axis equivalent circuit of a synchronous generator

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

Stator voltage equations.

$$e_d = p\Psi_d - \Psi_q \cdot \omega_r - R_a \cdot i_d \quad (1)$$

$$e_q = p\Psi_q + \Psi_d \cdot \omega_r - R_a \cdot i_q \quad (2)$$

$$e_0 = p\Psi_0 - R_a \cdot i_0 \quad (3)$$

Rotor voltage equtions:

$$e_{fd} = p\Psi_{fd} + R_{fd} \cdot i_{fd} \quad (4)$$

$$0 = p\Psi_{1d} + R_{1d} \cdot i_{1d} \quad (5)$$

$$0 = p\Psi_{1q} + R_{1q} \cdot i_{1q} \quad (6)$$

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 conditions. 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:

$$G(s) = (I + \triangle_m(s))G_o(s) \tag{7}$$

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

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

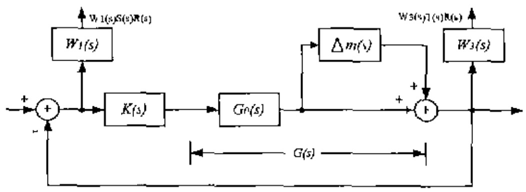


Fig. 4. Uncertainty model and the weighted sensitivity functions

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

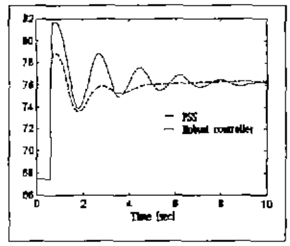
$$W_1(s) = \left[2.9\frac{s^2+s+1}{s+4}, 4.5\frac{s^2+s+1}{s+4}\right] \tag{8}$$

$$W_3(s) = \left[\frac{1.0}{0.03}\frac{s+10}{s^2+s+1}, \frac{0.9}{0.03}\frac{s+10}{s^2+s+1}\right] \tag{9}$$

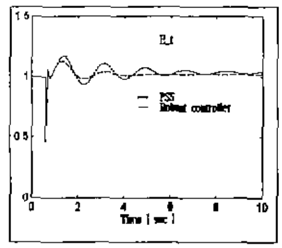
4. SIMULATION RESULT

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 stability of system under all operating conditions and can provide greater damping than the conventional PI controller.

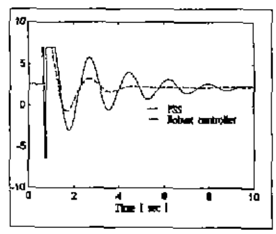
In Fig.5, a fault at high transimission is simulated. It is shown that the robust controller provides greater damping than the PSS.



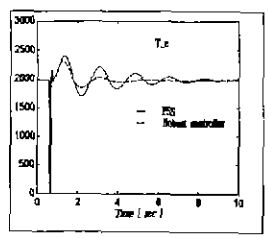
(a)



(b)



(c)



(d)

(a) Electrical angle degree
(b) Terminal voltage
(c) Exciter terminal voltage
(d) Electrical power

Fig.5. The Robust control & conventional 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.

REFERENCES

[1] P. Kundur, Power system stability and control, McGraw-Hill, Inc. 1995.

[2] Y.N.YU, Power system Dynamics, Academic Press, New York. 1983.

[3] R. Asgharian and D.C. Macdonald, "The design of turbine-generators optimal controllers including th effects of torsional modes of oscillations," IEEE Trans. Energy conversion, vol.3, no.2, 1988, pp. 230~234.

[4] P. Kundur. D. C Lee and H. M. Zein El-Din, " Power system stabilizers for thermal units: Analytical Techniquesand on-site validation," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-1, pp. 81~95. 1981.

[5] H. Othman, J. J. Sanchez-Casca, M. A. Kale and J. H Chow, "On the design of Robust power system stabilizer," Proceedings of the 28th Conference on decision and control, Tampa, Florida, pp. 1853~1857.Dec. 1989.

[6] Malik, O. P., Hope, G.S., Gorski, Y. M., Ushakov, V. A., Rackevich, A. L, "Experimental studies on adaptive microprocessor stabilizers for synchronous generator." IFAC Power System and Power Plant Control, Beijing pp. 125~130, 1986

[7] P. Kundur , M. KleinMalik, "Application of system stabilizers for enhancement of overall sysytem stability," IEEE Transactions on Power Systems, Vol. PS-4, pp. 61 4~626. 1989.

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