ROBUST LQG CONTROL OF PSS FOR DAMPING POWER SYSTEM OSCILLATIONS

[1]Ankit V. Chaudhari, [2]Dr. Bhavin J. shah,
[1]PG Student, L.D. College of Engineering, Ahmedabad, India,
[2]Professor, Electrical Engineering, Gujarat Technological University, Ahmedabad, India

Abstract: Power system oscillations [both local and inter area mode] posses threat to secure stable and reliable operation of power systems. Controlling power system stabilizer (PSS) are used to damp out these oscillation. This are prepares LQG (Linear Quadratic Gaussian) control of PSS for enhancing damping of power system oscillations. This PSS controller is design for two area system in machine test system.

Index Terms - power system oscillation damping, power system stabilizer (PSS), linear quadratic Gaussian (LQG) control.

I.INTRODUCTION

Electrical power systems, being highly nonlinear and dynamic behavior, give rise to numerous modes of oscillations. In interconnected power system, due to different reason stability limit violate and need advanced monitoring and control system. Thus, require robust control to damp these inter area and local area oscillations. Among different types of these oscillations, inter area oscillations is one major problem of electrical power systems. Inter area modes associated with machines in one area oscillates with another area, interconnected by weak tie lines. Poorly damped oscillations, whether local or inter-area, pose threats to secure system operation; inter area ones deserve rather more attention, as they involve Generating units in more than one area and contributions from individual units might produce larger oscillations in the tie-lines. The frequency range of inter area mode is 0.1 Hz to 1 Hz and local area mode frequency range is 1 Hz to 2 Hz. Minimum acceptable damping ratio is taken as 5 % and it is depends on operating conditions, system topology, characteristic of load and control parameter etc. To damp these oscillation power system stabilizer (PSS) is used. Conventional PSS ensure optimal performance only at their nominal operating and do not guarantee good performance over the entire operating range of the power system. This is due to external disturbance such as changes in loading conditions and fluctuations in the mechanical power. This external disturbance is in the form of certain frequency band. So that PSS is designed with improved performance and robustness properties. When the disturbance lies in a particular frequency range but is otherwise unknown then the LINEAR QUADRATIC GAUSSIAN (LQG) method is used for the knowledge of the disturbance model. The LQG control design method is considered to be a cornerstone of the modern optimal control theory and is based on the operation; inter area ones deserve rather more attention, as they involve Generating units in more than one area and contributions from individual units might produce larger oscillations in the tie-lines. The LQG control design method is considered to be a cornerstone of the modern optimal control theory and is based on the minimization of the cost function. These control method has been proved to be a significant method which could effectively solve the random noise problem and achieve optimum performance. In this paper using LQG theory is presented to overcome the above problems of linear controls by explicitly using a nonlinear model of the power system for control synthesis. The main aim of this is PSS is design to enhance the damping during low frequency oscillations.

II.LQG CONTROLLER

LQG control is a robust control method since noise in the state and an output equation is explicitly considered. Quantitative information about the noise is used in the controller design. In traditional LQG Control, it is assumed that the plant dynamics are linear and known, and that the measurement noise and disturbance signals (process noise) are stochastic with known statistical properties.

Consider the state space model of the plant,

$$x(t) = Ax(t) + \dot{} B\, u(t) + \Gamma \xi(t)$$
$$y(t) = Cx(t) + \theta(t)$$

Where, $\xi(t)$ and $\theta(t)$are random noises in the state equation and the output measurements, respectively. Assume that $\xi(t)$ and $\theta(t)$are zero mean Gaussian random processes with covariance matrices given by

$$E[\xi(t)\, \xi^T(t)] = \Xi \geq 0\,,$$

$$E[\theta(t)\, \theta^T(t)] = \Theta > 0,$$

Where, $E[x]$ denotes the mean value of x and $E[xx^T]$ is the covariance matrix of the zero mean Gaussian signal x. The random signals, $\xi(t)$ and $\theta(t)$ are further assumed to be mutually independent, i.e,
E $[\xi(t)\theta^T(t)] = 0$.
The performance index for optimal control is defined as,

$$J = E\left\{\int_0^{\infty} [z^T(t)Q\, z(t) + u^T(t)R\, u(t)]dt\right\}$$

Where, $z^T = Mx(t)$ is the linear combination of state vector $x(t)$ with M defined by the user to measure the performance. The constant weighting matrices Q and R are, respectively, a symmetrical semi positive-definite and a symmetrical positive-definite matrix, that is, $Q = Q^T \geq 0,\ R = R^T > 0$.
The LQG controller can be divided in two parts:

(1) The LQ optimal state feedback control, and
(2) The state estimation with disturbances (Kalman filter).

Optimal state feedback control:

The optimal state-feedback control law is given by,

$$u = -K_r x$$

Where, $K_r = R^{-1}B^TP_c$ and P_c is the unique symmetric positive semi definite solution of the algebraic Riccati equation (ARE)

$$A^TP_c + P_cA + Q - P_cR^{-1}B^TP_c = 0$$

Subject to (A, B) being stabilizable, $R > 0, Q \geq 0$, and (Q, A) has no unobservable modes on the imaginary axis.

Kalman filter:

In practical measuring all the state of plan is impossible, thus Kalman filter (Kalman estimator) is employed to provide the required estimates.
Kalman filter for the given plant,

$$\dot{\hat{x}} = A\,\hat{x} + Bu + K_f(y - C\hat{x}),$$

K_f is the Kalman filter gain minimizing $E\{[x - \hat{x}]^T[x - \hat{x}]\}$, given by

$$K_f = P_fC^TV^{-1}$$

Where P_f is the unique symmetric positive semi definite solution of the following are:

$$P_fA^T + AP_f - P_fC^TV^{-1}CP_f + \Gamma W\Gamma^T = 0$$

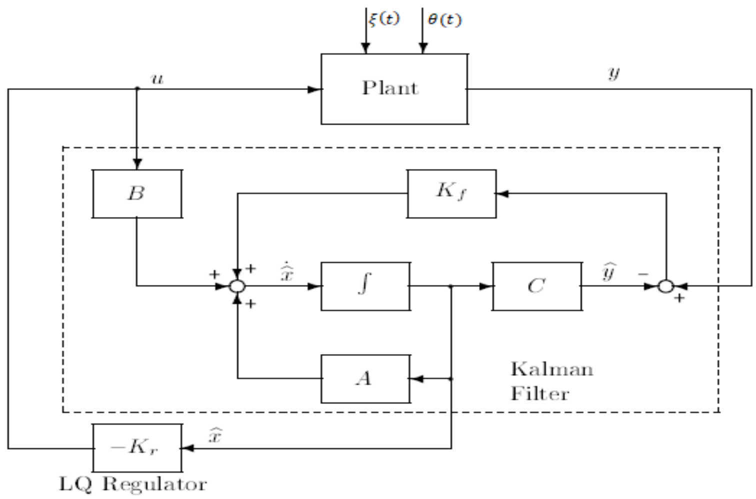
Subject to (C, A) being detectable, V> 0, W≥ 0 , and (A, $\Gamma W\Gamma^T$) has no uncontrollable modes on the imaginary axis.

The optimal control law in the LQG formulation becomes

$$u = -K_r\hat{x}$$

It can be shown from the previous list that Q , R, W and V are "tuning parameters" to be adjusted until an acceptable design arises, although choosing these parameters requires a great deal of experience and also trial-and-error.

LQG FORMULATION



III.SYSTEM MODELING

The damping control of power system design under study consists of two area system and is shown in fig.

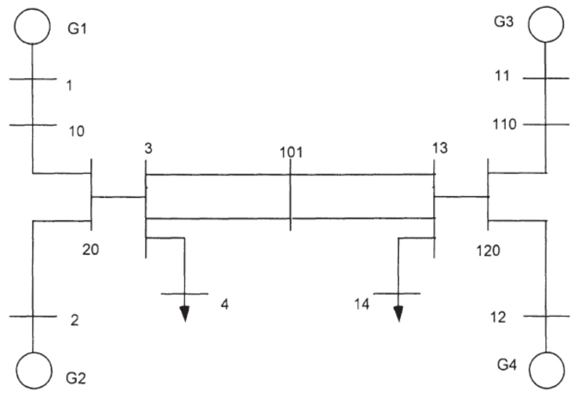


Fig. two area test system

More details on the system description and its characteristics including machine, excitation system, and network parameters can be found in. It is 4 machine 13 bus systems. In this test case base, MVA is 100 and frequency of the system is 60 Hz. . This model is useful for small signal stability studies. The complete power system with all necessary components has been modeled using power system toolbox integrated with MATLAB. Linearized models of the power system were computed using a power system toolbox, which consists of a set of coordinated MATLAB m files which models the power system components which are very necessary for power system stability and power flow studies. Using these toolbox find Eigen values, damping factor and frequency of this two area system in different load condition such as constant impedance, constant power, constant current, and combine of them. Using compass chart, know about which generator oscillate against other generator. The bar chart is used for participation factor analysis. The graph between speed participation factors vs. no. of the generator, which gives information for select suitable candidate generator for PSS placement. After PSS placement using this toolbox find out Eigen values, damping factor and frequency and compare this result with without PSS results. Modern control design methods such as LQG produce controllers of order at least equal to the order of the plant and usually higher with the incorporation of the required extra weights. Model order reduction is required to simplify the design procedure and, thus, the complexity of the final controller. The reduced plant used in the design must be a good approximation of the full order equivalent, for appropriate control design. So the systems are reduced, and LQG controller insert in system..

IV. RESULTS AND DISCUSSION

	WITHOUT LQG CONTROLLER			WITH LQG CONTROLLER		
TYPE OF LOAD	EIGEN VALUE	DAMPING	FREQUENCY	EIGEN VALUE	DAMPING	FREQUENCY
CONSTANT POWER	-0.0158 ± 0.1471i	0.106795	0.02342	-0.0542 ± 0.1709i	0.3023	0.02721
	-0.0157 ± 0.0982i	0.157873	0.015636	-0.0234 ± 0.0966i	0.235427	0.01538

	-0.0132 ± 0.0264i	0.44725	0.0042	-0.0204 ± 0.0255i	0.624712	0.00406
CONSTANT CURRENT	-0.0202 ± 0.1475i	0.13568	0.02348	-0.0626 ± 0.1739i	0.3387	0.02769
	-0.0125 ± 0.0964i	0.12859	0.01535	-0.0175 ± 0.0952i	0.18079	0.015159
	-0.0112 ± 0.0278i	0.37369	0.0044	-0.0162 ±0.0283i	0.517919	0.0045
CONSTANT IMPEDANCE	-0.0251 ± 0.1470i	0.168312	0.0234	-0.0705 ± 0.1767i	0.37057	0.028136
	-0.0089 ±0.0921i	0.09618	0.014665	-0.0115 ± 0.0905i	0.12605	0.01441
	-0.0086 ± 0.0290i	0.284313	0.004617	-0.0119 ± 0.0299i	0.36978	0.004761
50% CC + 50% CI	-0.0227 ± 0.1473i	0.1523	0.023455	-0.0668 ± 0.1756i	0.35555	0.02796
	-0.0104 ± 0.0945i	0.10939	0.01504	-0.0140 ±0.0931i	0.1487	0.014824
	-0.0098 ± 0.0285i	0.32517	0.004538	-0.0138 ± 0.0293i	0.42609	0.004665
50 % CP + 50% CI	-0.0202 ± 0.1475i	0.13568	0.02348	-0.0626 ± 0.1739i	0.3387	0.02769
	-0.0125 ± 0.0964i	0.11521	0.1535	-0.0175 ±0.0952i	0.180794	0.01515
	-0.0112 ± 0.0278i	0.37369	0.004426	-0.0162 ± 0.0283i	0.496799	0.004506

Table 4.1 Comparison of damping ratio and frequency with and without LQG controller in two area test case

Using the power system toolbox Eigen values analysis with and without LQG controller, and compare result. By inserting LQG controller damping ratio is improved and frequency reduction is minor in all cases. It is clear that using LQG controller PSS gives better performance and the oscillations in system is damp.

V. CONCLUSION

It can be conclude that small signal stability analysis in matlab using power system toolbox. For different type of loads, inter area and local area modes can find out using Eigen value analysis. Compass chart shows oscillation of generators in inter area mode and bar chart shows suitable generator for PSS placements. Inserting LQG controller in PSS in each case damping ratio of local mode and inter area mode are considerably improved. In case of two area test system constant impedance gives less stability improvement as compared to other cases.

VI. REFERENCES

(1) P. Kundur, *Power System Stability and Control*. New York, NY: Mc-Graw-Hill, 1994, p. 813.

(2) B. D. O. Anderson and J. B. Moore, *Optimal Control*- Linear Quadratic Methods: Prentice-Hall, 1989.

(3) A Study on LQG/LTR Control for Damping Inter-Area oscillations in Power Systems Argyrios C. Zolotas, *Member, IEEE*, Balarko Chaudhuri, *Student Member*, *IEEE*, Imad M. Jaimoukha, and Petr Korba.

(4) G. Radman, "Design of power system stabilizer based on LQG/LTR formulations," in *Proc. Ind. Appl. Soc. Ann. Meeting/Conf. Record 1992 IEEE*, pp. 1787–1792.

(5) LQG controller for enhancemet power system operation Ali M. YOUSEF1, Mohamed ZAHRAN2 & Ghareeb Moustafa3 Electrical Eng. Dept. Faculty of Engineering, Assiut University, 71516 Egypt, Electronics Research Institute, Photovoltaic Cells Departments, NRC

(6) IEEE Press, 1994. Blg., El-Tahrir St., Dokki, 12311-Giza, Egypt,Electrical Eng. Dept. Faculty of Engineering, Suez Canal University, Ismailia, Egypt,

(7) P. M. Anderson and A. A. Foud, *Power System Control and Stability*: IEEE Press, 1994.

(8) Charles A. Gross, Power System Analysis, John Wiley & Sons, New York, 1986

(9) J. M. Maciejowski, Multivariable Feedback Design, Addison-Wesley, New York, 1989