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MIMO-PID Controller For Deregulated environment

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Abstract: This assessment represents a Multi-Input-Multi-Output-Proportional-Integral-Derivative (MIMO-PID) controller for load frequency balance issues.The objective of load frequency control is to minimize the transient deviations in area frequency and tie-line power. To improve the robustness of the system the transfer function H_∞ norm is used. So the proposed technique is known as PIDH_∞ controller. The LFC problem is articulated as a H_∞ SOF (State Output Feedback) control approach to attain the decentralized robust MIMO-PIDH_∞ controller. H_∞ controller is used here for accomplishing stabilization with definite performance. The optimization difficult is formulated and iterative LMI algorithm is used to tune the control parameters of the MIMO-PIDH_∞ controller. The simulation results show the proposed strategy is very effective and guaranteed good robust performance against the parametric uncertainties and load changes.

Keywords: H∞ control; LMI; Area Control Error; Load Frequency Control; MIMO-PID control.

I. INTRODUCTION

In electrical power system due to deregulation there are unrivalled changes in system and theyraise to changes in the competitive market. The role of control in power system (either man-made operation or instinctive) is to shield operation by returning when subjected to disturbances. In other words control in power system means continuing of system within soothed limits of performance to disturbances, such as short circuits and generation loss or load loss.Lot of study is carried out and on work about this LFC in restructured power system [1]-[8]. With vibrant and bilateral contracts researchers have modified AGC conventional one [1]-[3]. New market schemes and their operational tools are proposed in [2]. Modified AGC is presented in [4]. LMI approach with decentralized strategy proposed in [7]. Neuro-fuzzy adaptive control is proposed in [8]. In this research three-area power system is specified as dynamic model. The distribution companies (DISCOs) can contact generation companies (GENCOs) for their power needs with different area contracts under independent service operator (ISO). For contract execution a matrix DISCO participation matrix (DPM) is used for conception [4]. The control problem is formulated as H∞ static output feedback (SOF) control approach to get novel decentralized MIMO-PID controller based on LMI algorithm. The robustness of proposed controller shown through simulation results.

II. PROPOSED CONTROL STRATEGY

In this section momentary view of decentralized MIMO-PIDH∞ control through LMI is followed

System model defined as:

$$\dot{x} = Ax + B_1 w + B_2 u$$

$$z_\infty = C_1 x + D_{12} u \qquad (1)$$
$$y = C_2 x$$

PID Controller defined as:

$$u = K_1 y + K_2 \int_0^t y\,dt + K_3 \frac{dy}{dt} \qquad (2)$$

Here K1,K2,K3 matrices are to be designed (PID Gains)

Output feedback H∞-control problem is to find controller of

$$u = Ky \qquad (3)$$

From above closed loop transfer function of infinite-form from Z∞ to w

$$(\|T_{z_\infty w}\|) < \gamma \qquad (4)$$

Consider $z_1 = x$ $z_2 = \int_0^t y\,dt$ and $z = \begin{bmatrix} z1 \\ z2 \end{bmatrix}$

The variable as viewed state vector of new system

$$\dot{z}_1 = \dot{x} = Az_1 + B_1 w + B_2 u$$

$$\dot{z}_2 = C_2 z_1 \qquad (5)$$

$$\dot{z}_1 = \dot{x} = C_1 x + D_{12} u \qquad (6)$$

PID problem is reduced through static output feedback (SOF) control system as

$$\dot{z} = \bar{A}z + \overline{B_1}w + \overline{B_2}u$$
$$\bar{z}_\infty = \overline{C}_1 z + \overline{D_{12}}u$$
$$\bar{y} = \overline{C_2}z + \overline{D_{21}}w$$
$$u = \bar{K}\bar{y}$$

Where

$$\bar{A} = \begin{bmatrix} A & 0 \\ C_2 & 0 \end{bmatrix}, \ \overline{B_1} = \begin{bmatrix} B_1 \\ 0 \end{bmatrix}, \ \overline{B_2} = \begin{bmatrix} B_2 \\ 0 \end{bmatrix},$$
$$\overline{C_1} = [C_1 \ \ 0], \overline{C_2} = [\overline{C_{21}} \ \ \overline{C_{22}} \ \ \overline{C_{23}}]^T,$$

$$\overline{D_{12}} = D_{12}, \ \overline{D_{21}} = [0 \ \ 0 \ \ C_2 B_1]^T \qquad (7)$$

And $\bar{K} = [\overline{K_1} \ \ \overline{K_2} \ \ \overline{K_3}]$ (8)

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Once $\overline{K}$ is found original PID gains can be obtained

$$K_3 = \overline{K_3}(I + C_2 B_2 \overline{K_3})^{-1},$$
$$K_2 = (I - K_3 C_2 B_2)\overline{K_2}$$
$$K_1 = (I - K_3 C_2 B_2)\overline{K_1} \quad (9)$$

LMI algorithm for $PIDH_\infty$ optimizing system in equation (4) follows

Step 1: From state space model in (1)
Compute $\overline{A}$, $\overline{B_1}$, $\overline{B_2}$, $\overline{C_1}$ and $\overline{C_2}$ by using (7)
and select performance index (γ)

Step 2: Select Q>0 and solve for riccati equation

$$\overline{A}^T P + P\overline{A} - P\overline{B_2}\,\overline{B_2}^T P + Q = 0, P > 0$$

Set $i = 1$ and $X_i = P$

Step 3: solve optimization problem for P_i, $\overline{K}$ and a_i
Optimization 1: minimize a_i subject to LMI constraints

$$\begin{bmatrix} \sum & P_i\overline{B_1} & (\overline{C_1} + \overline{D_{12}}\,\overline{K}\overline{C_2})^T & (\overline{B_2}^T P_i + \overline{K}\overline{C_2})^T \\ \overline{B_1}^T P_i & -\gamma & 0 & 0 \\ \overline{C_1} + \overline{D_{12}}\,\overline{K}\overline{C_2} & 0 & -\gamma & 0 \\ \overline{B_2}^T P_i + \overline{K}\overline{C_2} & 0 & 0 & -I \end{bmatrix} < 0 \quad (10)$$

Where $\sum = \overline{A}^T P_i + P_i\overline{A} - X_i\overline{B_2}\,\overline{B_2}^T P_i - P_i\overline{B_2}\,\overline{B_2}^T X_i + X_i\overline{B_2}\,\overline{B_2}^T X_i - aP_i$

a_i^* Denotes minimized value of a_i

Step 4: If $a_i \le 0$ the matrix pair $(P_i, \overline{K})$ solves the problem. Stop. Otherwise go to step 5

Step 5: solve optimization problem for P_i and $\overline{K}$

Optimization 2: minimize P_i subject to LMI constraint in (10) with $a_i = a_i^*$.

Optimal P_i denoted by P_i^*

Step 6: If $\| X\overline{B_1} - P_i^*\overline{B_1} \| < \in$ go to step 7 otherwise set $i = i+1$, $X_i = P_i^*$ and go to step.

Here $\in$ denotes tolerance (prescribed)

Step 7: If obtained $\overline{K}$ satisfies gain constant, it is desirable otherwise change weight n_i, Q and γ go to step 1.

III. DESIGN MODEL OF CONTROLLER

Projected model for three area power system with interconnections in deregulated background as [4] and [8] is shown in Fig 1.

State space model as follows:

$$\dot{x} = Ax + B_1 w + B_2 u$$
$$P(s): \quad z_\infty = C_1 x + D_{12} u \quad (11)$$
$$y = C_2 x + D_{21} w$$

Here

$$x = [\Delta X_{E1} \quad \Delta P_{t1} \quad \Delta f_1 \quad \Delta X_{E2} \quad \Delta P_{t2} \quad \Delta P_{tie12} \quad \Delta X_{E3} \quad \Delta P_{t3} \quad \Delta f_2 \quad \Delta X_{E4} \quad \Delta P_{t4} \quad \Delta P_{tie23} \quad \Delta X_{E5} \quad \Delta P_{t5} \quad \Delta f_3 \quad \Delta X_{E6} \quad \Delta P_{t6} \quad \Delta P_{tie31}]^T$$

$$w = [\Delta P_{L1} \quad \Delta P_{L2} \quad \Delta P_{L3} \quad \Delta P_{L4} \quad \Delta P_{L5} \quad \Delta P_{L6}]^T$$

$$u = [u_1 \quad u_2 \quad u_3]^T$$

z_∞ is a controlled output vector

$$y = [ACE_1 \quad ACE_2 \quad ACE_3 \quad \Delta f_1 \quad \Delta f_2 \quad \Delta f_3 \quad \Delta P_{tie12} \quad \Delta P_{tie23} \quad \Delta P_{tie31}]^T$$

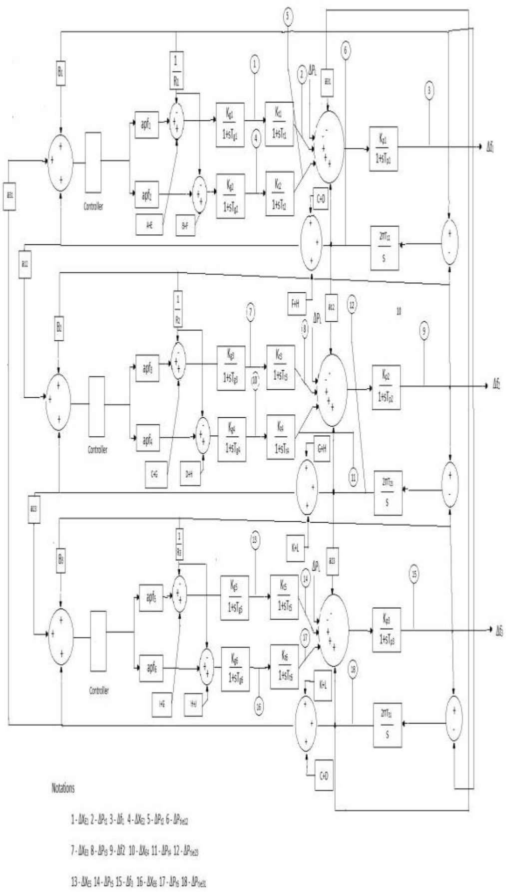
y is a measured output vector

Controlled output vector considered as follows

$$z_\infty = [n_1\Delta f_1 \quad n_2\Delta f_2 \quad n_3\Delta f_3 \quad n_4\Delta P_{tie12} \quad n_5\Delta P_{tie23} \quad n_6\Delta P_{tie31} \quad n_7 u_1 \quad n_8 u_2 \quad n_9 u_3]^T \quad (12)$$

Here n_1 to n_9 are constants and weight coefficients are chosen by designer.

Consider three area power system parameters in Fig 1. as K_g=1.0, T_g=0.08s, K_t=1.0, T_t=0.3s, R_i=2.4(Hz/pu), B_i=0.425(pu/Hz) K_P=120(pu/Hz), Tp=20s, T_{12}=0.0868s, T_{23}=0.0868s, T_{31}=0.0868s



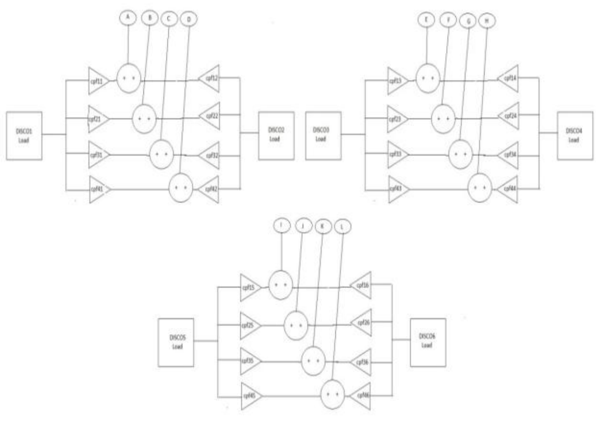


Figure1. Three area power system with cpfs.

IV. RESULTS

Free contracts transactions based scenario:

In this section all DISCOs are contracted with GENCOs as per DPM (Dynamic Participation Factor).

$$DPM = \begin{bmatrix} 0.5 & 0.25 & 0 & 0.3 & 0.8 & 0 \\ 0.2 & 0.25 & 0 & 0 & 0.1 & 0.1 \\ 0 & 0.25 & 1 & 0.7 & 0.1 & 0.1 \\ 0.3 & 0.25 & 0 & 0 & 0 & 0.8 \end{bmatrix}$$

All GENCOs in each area participate as follows

apf1=0.50 apf2=1-apf1=0.50
apf3=0.50 apf4=1-apf3=0.50
apf5=0.50 apf6=1-apf5=0.50

Load variations considered as

ΔP_{L1}=0.75pu ΔP_{L2}=0.75pu ΔP_{L3}=0.75pu
ΔP_{L4}=0.75pu ΔP_{L5}=0.75pu ΔP_{L6}=0.75pu

ΔP_{M1}=0.5*0.75+0.25*0.75+0*(0.75)+0.3*(0.75)+0*(0.75)+0*(0.75)=0.7875pu

Correspondingly

ΔP_{M2}=0.3375pu ΔP_{M3}=0.4275pu ΔP_{M4}=0.4125pu
ΔP_{M5}=0.5475pu ΔP_{M6}=0.1500pu

Power generated from GENCOs in area-I, II and III shown in Fig 3. With desired values of ΔP_{Mi}. Test results show robustness of the system.

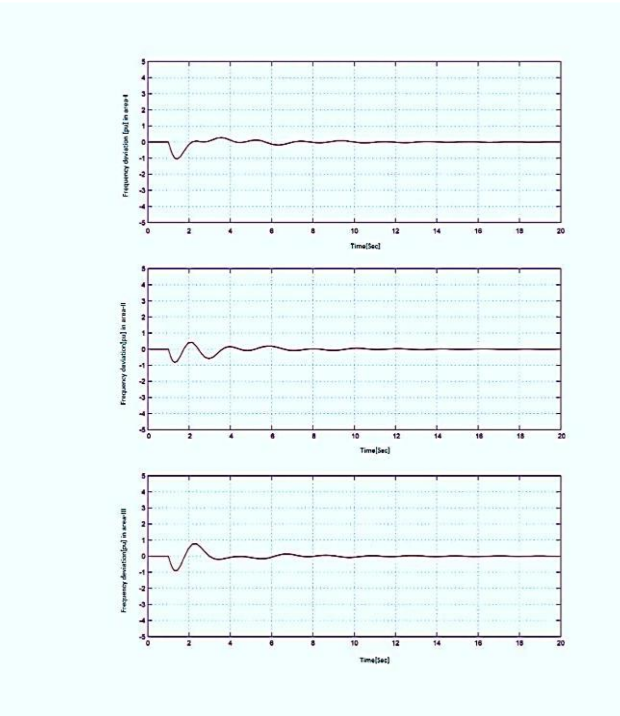


Figure2. Frequency deviations in corresponding areas

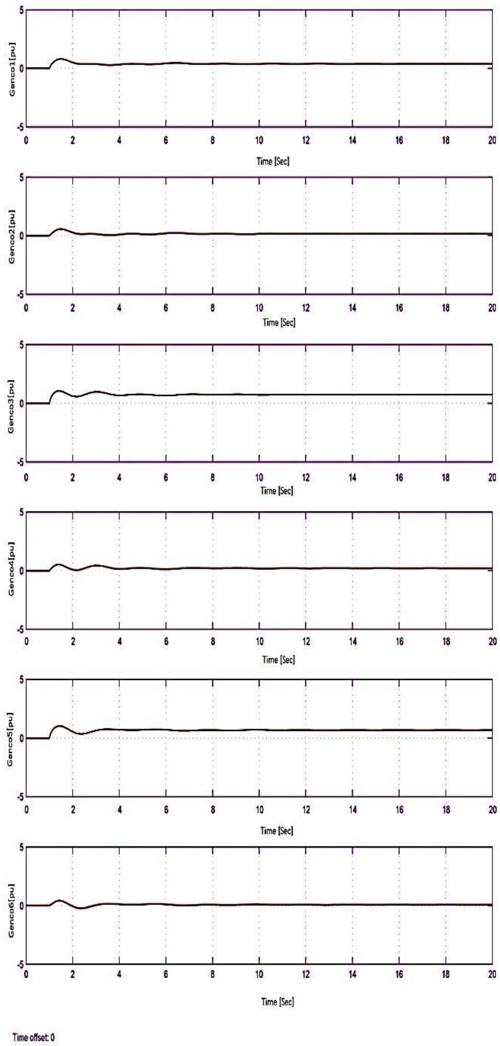


Figure3. Generated Power

V. CONCLUSION

In three area power system with reheat type thermal power stations this researchoffers MIMO-PID decentralized controller in restructured power system. To diminish effects of uncontrolled changes in system in area's inside loads and in interconnected loads control actions are calculated through LMI. For guaranteed performance and robustness this controller is effective and efficient against variations in loads and parametric uncertainties.

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REFERENCES

[1] R.D.Christie, and A.Bose, "Load Frequency control issues in power systems operation after deregulation" *IEEE Trans. Power Systems*, vol. 11, no. 3, pp. 1191-1200, Aug. 1996.

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

[2] J. Kumar, Kah-Hoe Ng, and G. Sheble, “AGC Simulator for price based operation part 1:a model” *IEEE Trans. Power Systems*, vol. 12, no. 2, pp. 527-532, May 1997.
[3] J. Kumar, Kah-Hoe Ng, and G. Sheble, “AGC Simulator for price based operation part II:case study results” *IEEE Trans. Power Systems*, vol. 12, no. 2, pp. 523-538, May 1997.
[4] V.Donde, M.A.Pai, and I.A.Hiskens, “Simulation and optimization after deregulation” *IEEE Trans. Power Systems,* vol. 16, no. 3, pp. 481-489, Aug. 2001.
[5] D.Rerkpreedapong, A. Hasanovic, and A.Feliachi, “Robust load frequency control using genetic algorithm and linear matrix inequalities”, *IEEE Trans. Power Syst.*, vol. 18, no. 2, pp. 855-861.
[6] H. Bewrani, Y. Mitani, and K. Tsuji, “Robust decentralized load frequency control using an iterative linear matrix inequalities algorithm”, *IEE Proc. Gener. Trans. Distrib.* Vol.151, no. 3, pp. 347-354, 2004.
[7] B.Tyagi and S. C. Srivastava, “A decentralized automatic generation control scheme for competitive electricity markets,” *IEEE Trans. Power System*, vol. 21, no. 1, pp. 312-320, 2006.
[8] S. H. Hosseini, and, A. H. Etemadi, “Adaptive neuro-fizzy inference system based automatic generation control,” *Elsevier, Electric Power Systems Research* vol. 78, pp. 1230-1239, 2008.
[9] Nilay Kumar. N. Shah, Chetan D. Kotwal, ”The State Space Modeling of Single, Two and Three ALFC of Power System Using Integral Control and Optimal LQR Control Method,” *IOSR Journal of Engineering,* Vol. 2(3) pp: 501-510, March 2012.
[10] Ahmed Bensenouci, A. M. Abdel Ghany, “Performance Analysis and Comparative Study of LMI-Based Iterative PID Load-Frequency Controllers of Single-Area Power System,” *WSEAS Trans. On. Power Systems,* issue no. 2, pp. 85-97, April 2010.

BIOGRAPHIES

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