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Load Frequency Control in Power System using Internal Model Control Technique

[1]Elakkiya.T, [2]Dr.R.Jayashree, Mrs.S.Jennathu Beevi[3]
[1]*M. Tech Power System Engineering B.S.Abdur Rahman University Vandalur, Chennai, Tamil Nadu*
[2]*Professor/EEE Department B.S.Abdur Rahman University UniversityVandalur, Chennai, Tamil Nadu*
[3]*Assistant Professor/EEE Department B.S.Abdur Rahman University UniversityVandalur, Chennai, Tamil Nadu*

ABSTRACT: *In this paper Load Frequency Control (LFC) for single area power system using Internal Model Control (IMC) technique is presented. Most load frequency controllers are primarily composed of an Integral controller. The main problem of the Integral controller is that it responds relatively slow to an error signal and that it can initially allow a large deviation at the instant the error is produced. This can lead to system instability. The main focus of this work is to obtain the fast error response and reduce the settling time using IMC controller. The output response of the IMC based PID controller is compared with that of an Integral controller.*

Keywords:- *Load Frequency Control (LFC), Internal Model Control (IMC), Disturbance Rejection, Integral controller (I), First Order Plus Dead Time (FOPDT).*

I. INTRODUCTION

Load frequency control (LFC) is the basic control mechanism in the power system operation and control. The main purpose of the load frequency is to keep the uniform frequency during the load change. Power networks consist of a number of utilities interconnected together and power is exchanged between the utilities over the tie-lines is scheduled on a priori contract basis. It is therefore important to have some degree of control over the net power on the tie-lines. Load frequency control (LFC) allows individual utilities to interchange power to aid in overall security, while allowing the power to be generated most economically.

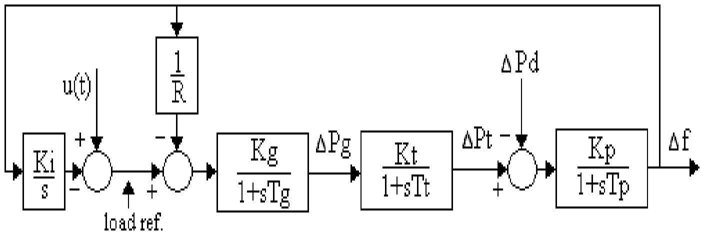

Figure 1 LFC Structure

The variation in Load Frequency is an index for normal operation of the power systems. When the load perturbation takes place, it will affect the frequency of other areas also. In order to control frequency of the power systems, various controllers are used in different areas, but due to the non-linearity in system components and alternators, these conventional feedback controllers could not control the frequency quickly and efficiently. The problem of controlling the real power output of generating units in response to changes in system frequency and tie-line power interchange within specified limits is known as load frequency control (LFC) [1]. Due to the increased complexity of modern power systems, advanced control methods were proposed in LFC, e.g., optimal control [2]–[4]; variable structure control [5]; adaptive and self-tuning control [6], [7]; intelligent control [8], [9]; and robust control [10]–[14].

II. PROBLEM STATEMENT

In order to keep the power system in normal operating state, a number of controllers are used in practice. As the demand deviates from its normal operating value the system state changes. Different types of controllers based on classical linear control theory have been developed in the past. Most load frequency controllers are primarily composed of an integral controller. The integrator gain is set to a level that compromise between fast transient recovery and low overshoot in the dynamic response of the overall system, this type of controller is slow and does not allow the controller designer to take into account the possible non-linearities in the generator unit.

Internal Model Control Technique which incorporates the system model in the control architecture can be used for the load frequency control. Internal Model Control Scheme also gives better and robust performance when there is a change in operating point.

III. DESIGN OF IMC

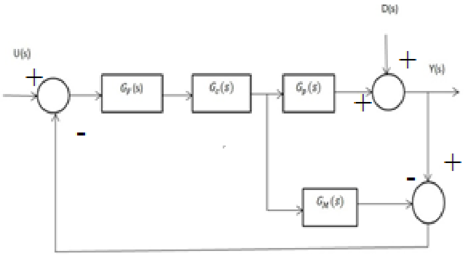

Figure 2 IMC Model

The structure is characterized by a control device consisting of the feedback controller Q(s), the real plant to be controlled $G_P(s)$, and a predictive model of the plant, i.e. the internal model $G_m(s)$. The internal model loop uses the difference between the outputs of G(s) and $G_m(s)$. This difference commonly known as an error, represents the effect of disturbances D(s) and plant / model mismatch if exists.

The procedure for designing IMC controller is

$$G_m(s) = G_m^+ G_m^- \qquad (1)$$

Such that G_m^+ is a non-minimum phase part and G_m^- is a minimum phase.

Define the IMC controller as

$$Q(s) = G_m^{-\,-1}(s)F(s) \qquad (2)$$

where F(s) is a low-pass filter of the form

$$F(s) = (1+\lambda_s) \qquad (3)$$

In (3),λ is a tuning parameter, which adjusts the speed of response of a closed-loop system and also removes plant / model mismatch which generally occurs at high frequency, that responsible for robustness n is a integer, chosen such that Q(s) becomes proper for physical realization.

we have,

$$G_c = \frac{1}{G_m G_F} \qquad (4)$$

where G_F, G_c are the filter and controller transfer functions respectively. In the absence of filter, the equation can be written as,

$$G_c = \frac{1}{G_m} \qquad (5)$$

3.1 IMC BASED PID CONTROLLER

The two area LFC structure transfer function model is of third order. It is reduced to First Order Plus Dead Time (FOPDT) model using process reaction curve method .The IMC based PID is designed for the FOPDT model .The IMC based PID parameters are obtained using the following reactions [15].

$$K_c = \frac{\tau_p + 0.50}{K_p(\lambda + 0.50)} \qquad (6)$$

$$\tau_i = \tau_p + 0.50 \qquad (7)$$

$$\tau_D = \frac{\tau_p \theta}{2\tau_p + \theta}$$

IV. NUMERICAL STUDIES

The transfer function of two area LFC is given by,

$$P(s) = \frac{250}{(s^3+15.88s^2+42.46s+106.2)} \qquad (9)$$

The third order transfer function model is reduced to FOPDT model which is

$$P(S) = \frac{K_{p}e^{-tds}}{\tau_p s+1} \qquad (10)$$

$$P(S) = \frac{2.47e^{-0.8s}}{0.7s+1} \qquad (11)$$

4.1 FOR NON-REHEAT TURBINE

For the FOPDT obtain the IMC based PID parameter using equation (6), (7), (8) are $k_c = 7.29$, $\tau_i = 2.6$, $\tau_D = 0.40$, $\theta = 1$, λ=0.1 , $\tau_p = 2.1$ .Using the above calculated PID parameters, the two area LFC with non-reheat turbine was simulated for a step disturbance of 10%.The results are compared with that of PI controller. It is evident from the graph that the damping is improved and settling time is also reduced in the case of IMC based PID controller.

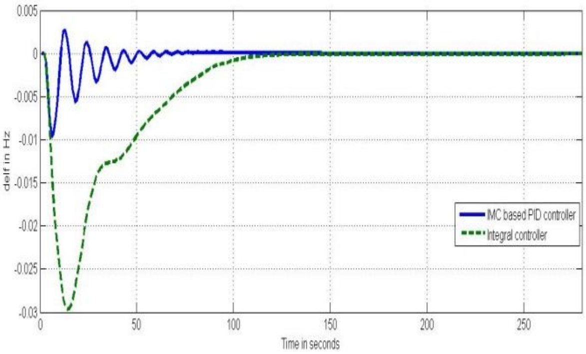

Figure 3 Frequency response of area1

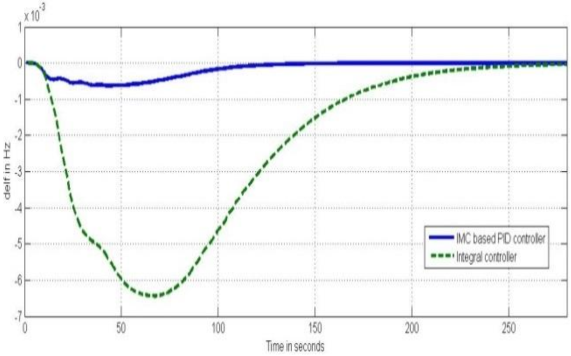

Figure 4 Frequency response of area 2

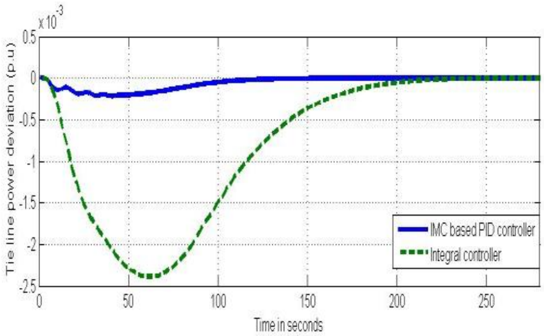

Figure 5 Output response of tie-line interchange Δp_{tie}

4.2 QUANTITATIVE COMPARISON FOR TWO AREA WITH NON-REHEAT TURBINE

The performance indices of Integral Absolute Error(IAE),Integral Squared Error(ISE),Integral Time Weighted Absolute Error(ITAE) of PI controller and IMC based PID controller for two area LFC with non-reheat turbine are calculated and presented in table1. From table 1 it is evident that the performance indices (i.e) the error values are reduced to the greater extent for IMC based PID controller.

	PI controller			**IMC based PID controller**		
	IAE	**ISE**	**ITAE**	**IAE**	**ISE**	**ITAE**
∆f1	**0.1020**	**5.85e^-010**	**0.4208**	**0.0102**	**5.577e^-014**	**0.0277**
∆f2	**0.1021**	**4.5663e^-004**	**1.1878**	**0.0059**	**2.5542e^-006**	**0.0398**
∆ptie	**0.0334**	**5.5937e^-005**	**0.3357**	**0.0019**	**2.7818e^-007**	**0.0125**

Table 1 Comparison of error values for PI controller and IMC based PID controller

4.3 FOR REHEAT TURBINE

For the FOPDT obtain the IMC based PID parameter using equation (6), (7), (8) are $k_c = 5.250$, $\tau_i = 2.35$, $\tau_D = 0.543$, $\theta = 1.7$, λ=0.1 , $\tau_p = 1.5$ .Using the above calculated PID parameters, the two area LFC with reheat turbine was simulated for a step disturbance of 10%.The results are compared with that of PI controller. It is evident from the graph that the damping is improved and settling time is also reduced in the case of IMC based PID controller.

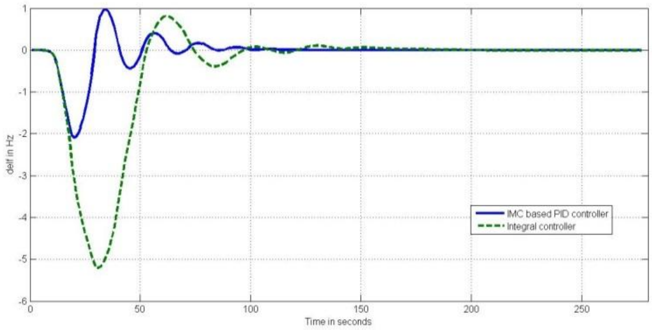

Figure 6 Frequency response of area1

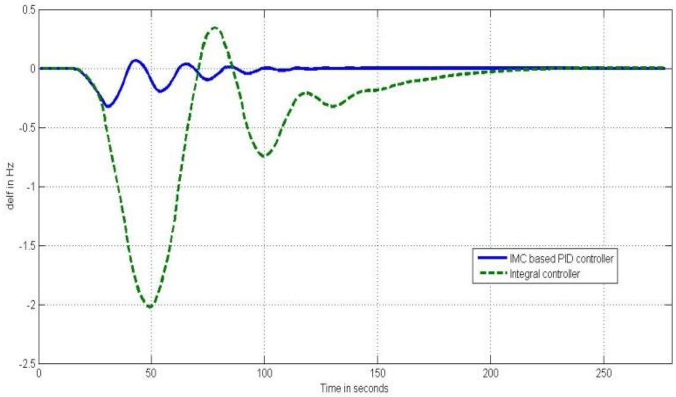

Figure 7 Frequency response of area 2

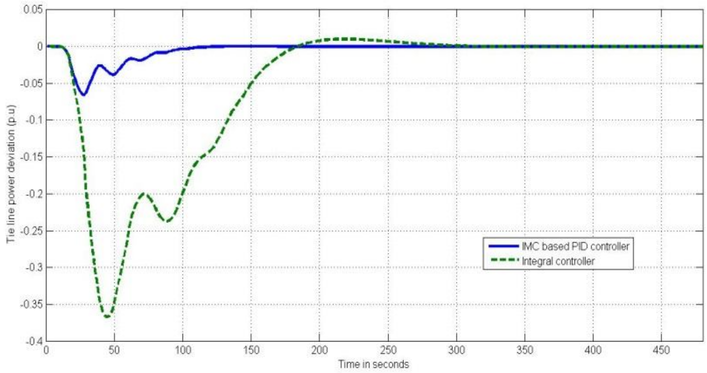

Figure 8 Output response of tie-line interchange Δp_{tie}

4.4 QUANTITATIVE COMPARISON FOR TWO AREA WITH REHEAT TURBINE

The performance indices of Integral Absolute Error(IAE),Integral Squared Error(ISE),Integral Time Weighted Absolute Error(ITAE) of PI controller and IMC based PID controller for two area LFC with reheat turbine are calculated and presented in table2. From table 2 it is evident that the performance indices (i.e) the error values are reduced to the greater extent for IMC based PID controller.

	PI controller			IMC based PID controller		
	IAE	ISE	ITAE	IAE	ISE	ITAE
Δf1	14.1167	46.0099	50.2117	3.2992	3.4390	7.0436
Δf2	11.1452	10.2889	99.9008	0.7675	0.1262	2.7799
Δptie	3.6790	0.7232	37.4418	0.2192	0.0074	0.7964

Table 2 Comparison of error values for PI controller and IMC based PID controller

4.5 FOR HYDRO TURBINE

For the FOPDT obtain the IMC based PID parameter using equation (6), (7), (8) are $k_c = 1.36$, $\tau_i = 8.25$, $\tau_D = 1.06$, $\theta = 2.5$, λ=0.1 , $\tau_p = 7$ .Using the above calculated PID parameters, the two area LFC with hydro turbine was simulated for a step disturbance of 10%.The results are compared with that of PI controller. It is evident from the graph that the damping is improved and settling time is also reduced in the case of IMC based PID controller.

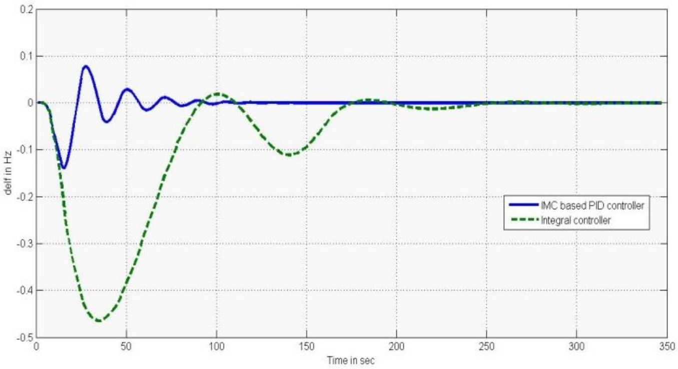

Figure 9 Frequency response of area 1

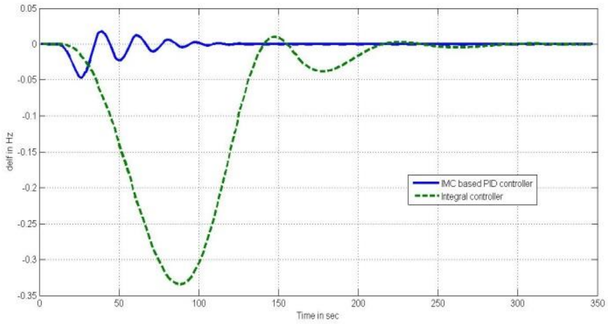

Figure 10 Frequency response of area 2

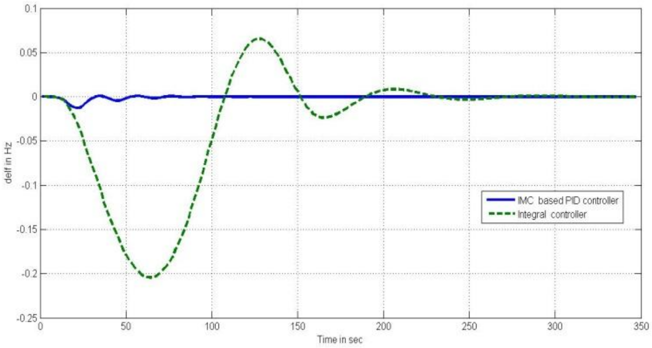

Figure 11 Output response of tie-line interchange Δp_{tie}

4.6 QUANTITATIVE COMPARISON FOR TWO AREA WITH HYDRO TURBINE

The performance indices of Integral Absolute Error(IAE),Integral Squared Error(ISE),Integral Time Weighted Absolute Error(ITAE) of PI controller and IMC based PID controller for two area LFC with hydro turbine are calculated and presented in table3. From table 3 it is evident that the performance indices (i.e) the error values are reduced to the greater extent for IMC based PID controller.

	PI controller			**IMC based PID controller**		
	IAE	**ISE**	**ITAE**	**IAE**	**ISE**	**ITAE**
Δf1	**5.9776**	**0.7211**	**191.0032**	**0.0714**	**4.9041e^-004**	**0.5698**
Δf2	**10.4270**	**2.3421**	**365.0635**	**0.3557**	**0.0080**	**4.0880**
Δptie	**5.9776**	**0.7211**	**191.0032**	**0.0714**	**4.9041e^-004**	**0.5698**

Table 3 Comparison of error values for PI controller and IMC based PID controller

V. CONCLUSION

An IMC based PID design for load frequency control of two area power system was studied. Using IMC based PID controller the peak overshoot and settling time for the non-reheat turbine is -0.01 and 12 for area1,-0.3and 20 for area2,-0.01and 22 for tie line. For reheat turbine the overshoot and settling time values are -2 and 12 for area 1,-0.35 and 14 for area 2,-0.06 and 15 for tie line. For hydro turbine the overshoot and settling time values are -0.15 and 40 for area 1,-0.05 and 45 for area2,-0.01 and 30 for tie line. Simulation results for two area system showed that IMC based PID controller gives better results when compared with the conventional PI controller.

REFERENCES

[1]. P. Kundur, Power System Stability and Control. New York: McGraw- Hill, 1994.
[2]. C. E. Fosha and O. I. Elgerd, "The megawatt-frequency control problem: A new approach via optimal control theory," IEEE Trans. Power App. Syst., vol. PAS-89, no. 4, pp. 563–567, 1970.
[3]. R. K. Cavin, M. C. Budge, and P. Rasmussen, "An optimal linear system approach to load frequency control," IEEE Trans. Power App. Syst., vol. PAS-90, no. 6, pp. 2472–2482, 1971.
[4]. M. Calovic, "Linear regulator design for a load and frequency control theory," IEEE Trans. Power App. Syst., vol. PAS-91, no. 6, pp. 2271–2285, 1972.
[5]. N. N. Bengiamin and W. C. Chan, "Variable structure control of electric power generation," IEEE Trans. Power App. Syst., vol. PAS-101, no. 2, pp. 376–380, 1982.
[6]. C. T. Pan and C. M. Liaw, "An adaptive controller for power system load-frequency control," IEEE Trans. Power Syst., vol. 4, no. 1, pp. 122–128, Feb. 1989.
[7]. M. A. Sheirah and M. M. Abd-EI-Fattah, "Improved load frequency self-tuning regulator," Int. J. Control, vol. 39, no. 1, pp. 143–158, 1984.
[8]. A. Demiroren, N. S. Sengor, and H. L. Zeynelgil, "Automatic generation control by using ANN technique," Elect. Power Compon. Syst., vol. 29, no. 10, pp. 883–896, 2001.
[9]. Y. L. Abdel-Magid and M. M. Dawoud, "Optimal AGC tuning with the genetic algorithms," Elect. Power Syst. Res., vol. 38, no. 3, pp. 231–238, 1996.
[10]. Y.Wang, R. Zhou, and C.Wen, "Robust load-frequency controller design for power systems," Proc. Inst. Elect. Eng. C, vol. 140, no. 1, pp. 11–16, 1993.
[11]. Z. Q.Wang and M. Sznaier, "Robust control design for load frequency control using synthesis," in Proc. Southcon/94 Conf. Record, Orlando, FL, Mar. 1994, pp. 186–190.
[12]. G. Ray, A. N. Prasad, and G. D. Prasad, "A new approach to the design of robust load-frequency controller for large scale power systems," Elect. Power Syst. Res., vol. 51, no. 1, pp. 13–22, 1999.
[13]. M. Azzam, "Robust automatic generation control," Energy Convers. Manage., vol. 40, no. 13, pp. 1413–1421, 1999.
[14]. A. Khodabakhshian and N. Golbon, "Robust load frequency controller design for hydro power systems," in Proc. IEEE Conf. Control Applications (CCA), Aug. 2005, pp. 1510–1515.
[15]. B.Wanye Bequette, " process control modelling, design and simulation"PHI Learning private limited,new delhi-110001,2010,pp.195-200.