APPLICATION OF CLASSICAL STEP RESPONSE METHOD TO DETERMINE THE PID CONTROLLER PARAMETERS FOR A 500 MW STEAM GENERATOR IN A THERMAL POWER PLANT

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ABSTRACT

PID controller is the most widely used controller in industries. There are many important functions for PID controller. Feedback is provided; offsets are eliminated by integrator; future anticipated through derivative action. PID control loops are employed in more than 95% of the control loops. Generally, the PID controller parameters are calculated based on trial and error method. In different disciplines of engineering, attempts have been made to propose many new methods for controlling process parameters. Whenever PID control is chosen, iterative heuristic optimization algorithms (soft computing techniques) have been proposed to optimally determine the PID parameters. In this work, the authors have successfully applied the classical tuning methods such as Ziegler Nichols and CHR tuning methods to calculate the PID parameters. The step response method is employed to calculate the 'a' and 'L' which is used to determine the PID parameters. This is applied to calculate the PID controller parameters for a 500 MW steam generator in a thermal power plant.

Keywords: Step response, calculation of PID controller parameters, Ziegler-Nichols method, CHR method, Boiler control.

1. INTRODUCTION

The design of PID controllers by various methods and its features are demonstrated in [1-17]. The application of this PID controller in thermal plants is proved in [18-28]. The Z-N step response method and CHR method is governed by two parameters 'a' and 'L'. CHR method is a modification of Z-N method and observed that tuning formula for set point changes and load disturbances are different. CHR method also proposed and used 'quickest response without overshoot and 'quickest response with 20% over-shoot as performance criteria. As a result of the motivation provided by certain studies conducted by Electric Power Research Institute [29] and certain remarks expressed by Astrom [30], the authors have applied the classical tuning control algorithms due to step response method of Ziegler-Nichols and Chein, Hrones, Reswick explained in [12-14] inorder to calculate the controller parameters for main streem pressure control of 500 MW steam generator.

2. System Description: A Steam generator (boiler) is an equipment which is used to produce heat which in turn converts water to steam. The generated saturated steam is sent to a turbine coupled to a generator to produce electricity. The schematic diagram of a steam generator is shown in Figure 1.

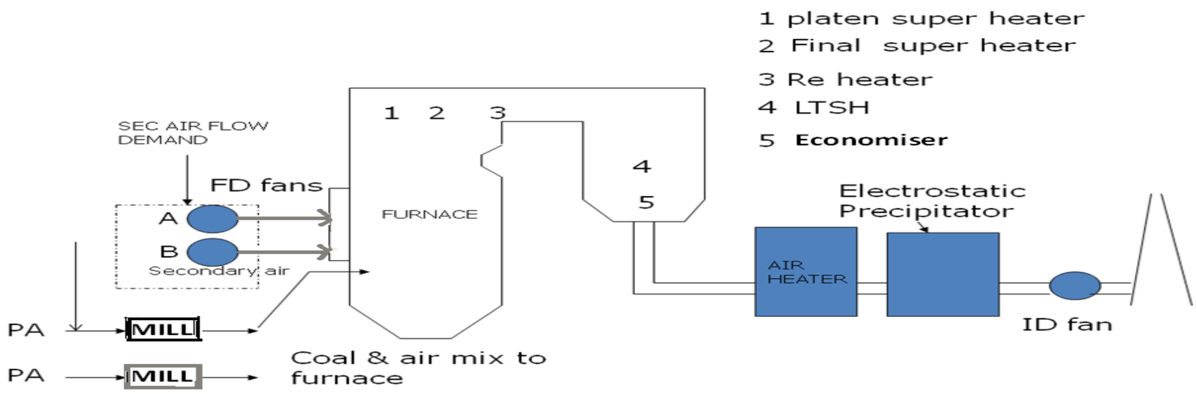

Fig. 1: Schematic diagram of a steam generator

3. Boiler Demand Signal: In Thermal power plants, boiler demand signal as the input signal is to be regulated to control the steam pressure. The main steam (MS) pressure at the boiler outlet remains constant if the steam production in circulation system is equal to the demand of steam at the outlet of the boiler. The boiler demand signal which regulates the combustion process is identified as the signal to be manipulated to control the main steam pressure. The boiler demand signal is derived based on any of three modes of the operation of the steam power plant. The three modes are Boiler Following Mode, Turbine Following Mode and Coordinated mode.

4. Features of PID Controllers: PID controllers are employed for highly interactive and complex systems. In thermal power plants, PID controllers are used to control important control loops associated with boiler and turbine. Some of the important process parameters to be controlled in a boiler are main steam pressure, main steam temperature, drum water level etc. Such parameters are necessary to be maintained within their limits. Hence finding the optimum parameters of the respective PID controllers is essential. In this research work, the tuning methods like Ziegler-Nichols method and CHR tuning method are employed. Z-N method is well suited for set point changes while the CHR method is suited for both set-point changes and load variations.

Controller para-meters for Ziegler-Nichols and CHR load disturbance response methods (0% overshoot and 20% overshoot) are shown in Table 1 & 2 respectively. The PID para-meters are calculated based on the Table 1 to Table 2.

Table 1: Z-N Tuning Method

CONTROLLER	K	T_i	T_d
P	1/a		
PI	0.9/a	3L	
PID	1.2/a	2L	0.5L

Table 2: CHR Method

OVERSHOOT	0%			20%		
CONTROLLER	K	T_i	T_d	K	T_i	T_d
P	0.3/a			0.7/a		
PI	0.6/a	4L		0.7/a	2.3L	
PID	0.95/a	2.4L	0.42L	1.2/a	2L	0.42L

5. Evaluation of PID Controller Constants

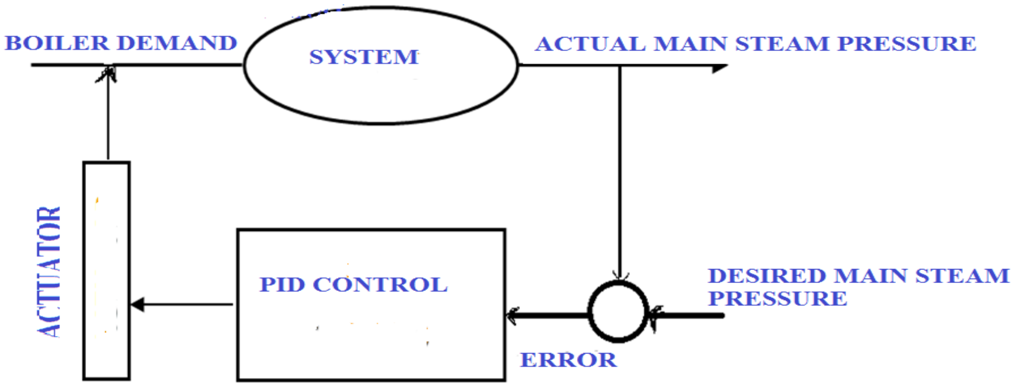

Fig. 2 Block diagram of the system

Figure 2 shows the general block diagram representation of the system under study. The important function in the entire system is the determination of the optimum PID controller parameters. The boiler demand signal is the manipulated signal to the boiler to control the main steam pressure. A step change in the manipulated variable is given and the main steam pressure response is obtained. The values of 'a' and 'L' are determined and the PID parameters are calculated using Z-N method and CHR method with 0% overshoot and 20% overshoot. Figure 3 depicts the calculation of 'a' and 'L'.

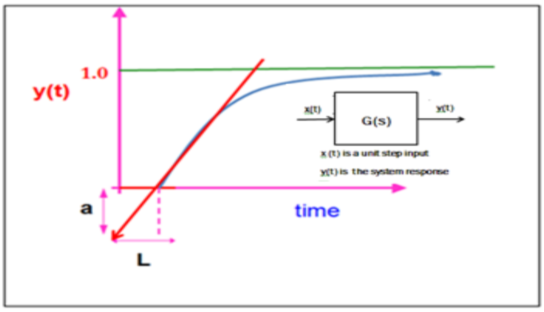

Fig. 3: Calculation of 'a' and 'L'

6. Generation of Step response

The mathematical model of a 500 MW coal fired thermal power plant available in The Centre of Excellence for simulators, BHEL, Hyderabad, India is used in the simulation. The validated non-linear model is studied and all the control loops are operated in the auto mode. Once the steady state is achieved, it is transferred to manual mode. A step change in boiler demand signal is given and the open loop response of main steam pressure is recorded. The main steam pressure variations with respect to time is given in Fig. 4.

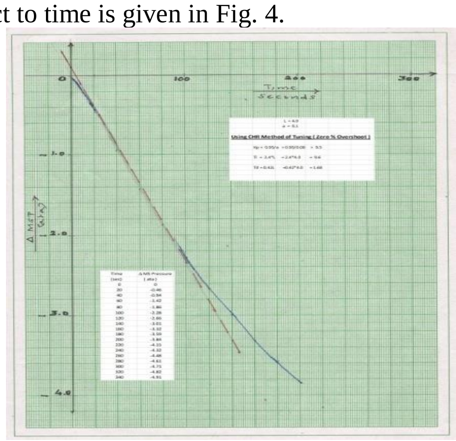

Fig. 4: MS pressure variation due to step change in Boiler Demand Signal

The values of 'a' and 'L' required for calculating the PID controller constants are extracted from Fig. 4 (a = 0.1 ata and L= 40 seconds).

7. Results and Discussion

Based on these values, the PID controller constants were determined and the values due to different methods are given in Table 3. From the open loop response of the Main steam pressure of the 500 MW steam generator of a thermal power plant, the PID parameters which are based on the classical step response method were calculated.

Table 3. Calculated PID controller constants

Tuning method / PID values	Ziegler Nichols method	CHR method with 0% over shoot	CHR method with 20% over shoot
P	12	9.5	12
I	80	96	80
D	20	16.8	16.8

8. CONCLUSION

In this paper, the PID controller parameters are evaluated based on well established procedures and not based on the trial and error method. Ziegler Nichols method and CHR tuning method with 0% overshoot and 20% overshoot were employed in the determination of the PID controller parameters from the open loop step response of a 500 MW steam generator whose mathematical model had been developed based on the detailed first principle for coal fired power plants. The PID controller values were calculated based on the step response of the boiler by subjecting it to a change in the boiler demand signal.

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REFERENCES

[1] Feng Lin, Robert D. Brandt,George Saikalis, Selftuning of PID controllers by Adaptive Inter-action, American Control Conference, June (2000)

[2] Sigurd Skogestad, Probably the best simple PID tuning rules in the world, Journal of Process Control (2001)

[3] J.C. Basilio, S.R. Matos, Design of PI and PID Controllers with Transient Performance Specification, IEEE Transactions on Education, November (2002)

[4] H.B. Patel, S.N. Chaphekar, Developments in PID controllers: A Literature Survey. International Journal of Engineering Innovation and Research (2012)

[5] Sigurd Skogestad, Simple analytic rules for model reduction and PID controller tuning, Modeling, Identification and Control (2004)

[6] Alenany, O. Abdelrahman, I. Ziedan, Simple Tuning Rules of PID Controllers for Integra-tor/Dead time Processes ACSE 05 Conference December (2005)

[7] Finn Haugen, The Good Gain method for PI(D) controller tuning, TechTeach Article, July (2010)

[8] David Di Ruscio, On Tuning PI Controllers for Integrating Plus Time Delay Systems Modeling, Identification and Control (2010)

[9] Hitay Özbaya, Catherine Bonnetb, André Ricardo Fioravanti, PID controller design for fractional-order systems with time delays, Systems and Control Letters, November (2011).

[10] Fabrizio Padula , Antonio Visioli, Tuning rules for optimal PID and fractional-order PID controllers Journal of Process Control, January (2011)

[11] K.J. Åström, T. Hägglund, C.C. Hang ,W.K. Ho, Automatic tuning and adaptation for PID controllers - a survey, Control Engineering Practice, August 1993

[12] Astrom, K.J., Hagglund, T., Revisiting the Ziegler – Nichols step response method for PID control, Journal of Process control 14: 635-650 (2004)

[13] Astrom, K.J., Hagglund, T the Ziegler – Nichols step response method for PID control, Journal of Process control January (1995)

[14] Astrom, K.J., Hagglund, T., PID Controllers: Theory, Design and Tuning, the Instrumentation, Systems and Automation Society; 2 Sub edition, January 1, (1995).

[15] Husain Ahmed, Abha Rajoriya, Performance Assessment of Tuning Methods for PID Controller Parameter used for Position Control of DC Motor, International Journal of Science and Technology (2014)

[16] Galal A. Hassaan, Tuning of A Pd-Pi Controller Used With An Integrating Plus Time Delay Process, International Journal of Scientific and Technology Research, September (2014)

[17] Daya Sagar Sahu, Sunil Sharma, A survey paper on PID control systems, International journal of Engineering Trends and Technology, March (2015)

[18] Shauyuan Li, Hongbo Liu, Wen-Jian Cai, Yeng-Chai Soh, Li-Hua Xie A new coordinated control strategy for boiler-turbine system of coal-fired power plant, IEEE transactions on Control Systems Technology, (2005)

[19] Wen Tan, Horacio J. Marquez, Tongwen Chen, Jizhen Liu, Analysis and control of a nonlinear boiler – Turbine Unit. Journal of Process Control 15: 883-891 (2015).

[20] Batool Labibi, Horacio Jose Marquez, Tongwen Chen, Decentralised robust PI controller design for an industrial boiler, Journal of Process Control 19: 216-230 (2009).

[21] Tan W., Liu J.Z., Fang F., Chen Y.Q., Tuning of PID controllers for boiler–turbine units, ISA Transactions 43: 571–583 (2004).

[22] Beheshti, M.T.H., Rezaee, M.M., A new hybrid boiler master controller, Proceedings of the American Control Conference Pp. 2070-2075 (2002).

[23]. Huanpao Huang, Nonlinear PID controller and its applications in power plants, Proceedings Power Con International Conference on Power System Technology 3: 1513-1517 (2002).

[24] Tan W, Liu JZ, Fang F, Chen YQ, Tuning of PID controllers for boiler–turbine units. ISA Transactions 43: 571–583 (2004).

[25] Shao Yuan Li, Hongbo Liu, Wen-JianCai, Yeng-Chai Soh, Li-HuaXie, A New Coordinated Control Strategy for Boiler-Turbine System of Coal-Fired Power plant, IEEE Transactions on Control Systems Technology 13: 943-954 (2005).

[26] Dharmalingam S., Sivakumar L. and Umapathy M., Optimizing boiler performance for varying Coals using mathematical modeling and embedded controller, 54th Annual ISA POWID Symposium at Charlotte, NC, USA from 6-8 June (2011),

[27] Dharmalingam, S., Sivakumar, L. Anandhi T. and M. Umapathy, Improved method to mitigate the effect of coal fuel switching on Critical Process Parameters of a Steam Generator in a Thermal Power plant, Proc. IMechE Part A: J. Power and Energy 225(8): 1026- 1040 (2011)

[28] Dharmalingam, S., Determination of accumulation value for the evaporator system of fossil fuel Boilers and a novel control system design for fuel switching, Ph.D Thesis, Department of Instrumentation and Control Engineering, NIT, Trichy, July (2011).

[29] Waddington, J., Comparative evaluation of control strategies, EPRI Report– Technical results Product ID: TR-107118, Power Technology center, England, Dec (1998).

[30] Astrom, K.J., Hagglund, T., The Future of PID control-Control Engineering Practice 9: 1163-1175 (2001).