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Analysis of Different Controllers used for Boiler Drum Level Control by using LabVIEW Simulation

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ABSTRACT

An intelligent model is developed to control the water level in boiler drum. There are three different types of boiler control such as (i) Single element boiler drum level control, (ii) Two element boiler drum level control and (iii) Three element boiler drum level control. This paper provides the knowledge about the Fuzzy PID Controller and the various PID controller design methods such as Zeigler-Nichols method, Tyreus-Luyben method, Internal Model Control (IMC). Comparative study is made on the performance of the PID and Fuzzy PID controller for better control system design.

KEYWORDS: *Boiler drum level control, Zeigler-Nichols method, Tyreus-Luyben method, Internal Model Control, Fuzzy PID controller*

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I. INRODUCTION

Boiler is defined as a closed vessel in which steam is produced from water by the combustion of fuel. Generally, in boilers steam is produced by the interaction of hot flue gases with water pipes which is coming out from the fuel mainly coal or coke. In boilers, chemical energy of stored fuel is converted into the heat energy and this heat energy is absorbed by the water which converts them into a steam. Drum Level Control Systems are used extensively throughout the process industries. It is used to control the level of boiling water contained in boiler drums and provide a constant supply of steam. There are three different types of boiler drum level control:

A. single element boiler drum level control
B. two element boiler drum level control
C. three element boiler drum level control

The most basic and pervasive control algorithm used in the feedback control is the Proportional Integral and Derivative (PID) control algorithm. A proportional-integral-derivative (PID) controller is a generic control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process control inputs. In this paper, two input and three output fuzzy PID controller is designed. The inputs are the error and the error rate (change in error) and outputs are the values of K_p, K_i and K_d. The objective is to find the fuzzy relations among K_p, K_i, K_d, error and error rate. With continuous testing, the three output parameters are adjusted so as to achieve good stability.

The proposed work illustrates how to design Fuzzy PID Controller and the various PID controller design methods such as Zeigler-Nichols method, Tyreus-Luyben method, Internal Model Control (IMC) using LabVIEW.

The followings of the paper includes, Section II describing the boiler drum level control and control strategies. In Section III development of various controllers using LabVIEW. In Section IV result and comparison between the boiler performances is discussed. The paper concludes in Section V.

II. BOILER DRUM LEVEL CONTROL STRATEGIES

Drum Level Control Systems are used extensively throughout the process industries and the utilities to control the level of boiling water contained in boiler drums on process plant and help provide a constant supply of steam The purpose of the drum level controller is to bring the drum up to level at boiler start-up and maintain the level at constant steam load. A dramatic decrease in this level may uncover boiler tubes, allowing them to become overheated and damaged. An increase in this level may interfere with the process of separating moisture from steam within the drum, thus reducing boiler efficiency and carrying moisture into the process or turbine. Boiler drum water level control is critical to secure operation of the boiler and the steam turbine.

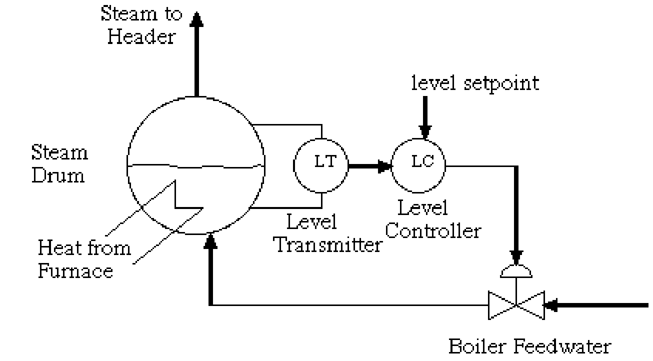

Fig.1 Control Instrumentation Diagram for Boiler

Control strategies are necessary for any system to perform accurately. Some of these are given below.

A. Ziegler-Nichols Method

The Ziegler-Nichols closed-loop tuning technique was perhaps the first rigorous method to tune PID controllers. The technique is not widely used today because the closed-loop behavior tends to be oscillatory and sensitive to uncertainty.

Table .1 Ziegler-Nichols Parameter

Control Type	Kp	Ki	Kd
P	0.50 Ku	-	-
PI	0.45 Ku	1.2 Kp/ Pu	-
PID	0.60 Ku	2 Kp/ Pu	KpPu/ 8

B. Tyreus-Luyben Method

This method is introduced by Tyreus-Luyen. In this method, the K_i and K_d gains are first set to zero. The *P* gain is increased until it reaches the ultimate gain K_u, at which the output of the loop starts to oscillate.

Table.2 Tyreus-Luyben Parameter

Control	Kp	Ki	Kd
PI	0.3125 Ku	Kp/ 2.2 Pu	-
PID	0.4545 Ku	Kp/ 2.2 Pu	KpPu/ 6.3

C. Internal Model Control

The Internal Model Control (IMC) based PID structure uses the process model as in IMC design. In the IMC procedure, the controller $G_c(s)$ is directly based on the invertible part of the process transfer function. The IMC results in only one tuning parameter which is filter tuning factor but the IMC based PID tuning parameters are the functions of this tuning factor.

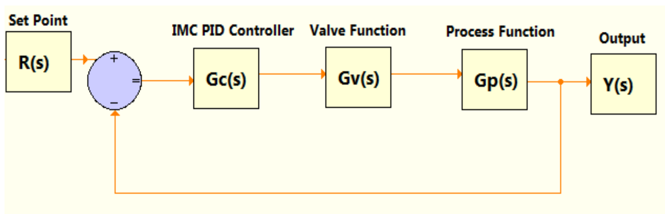

Fig.2 IMC Structure

When a disturbance affects a process under feedback control it is necessary for a measured process output to change before corrective action is taken to change the manipulated input. It would be preferable to have a sensor that measures the disturbance and adjusts the manipulated input before the process output changes. This type of control strategy is known as feed forward IMC control.

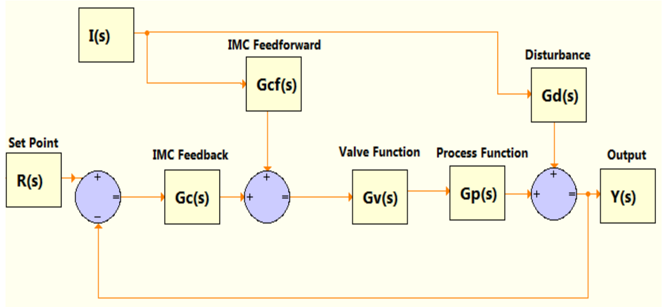

Fig.3 IMC FeedForward Structure

Cascade control involves the use of multiple measurements and a single manipulated input.

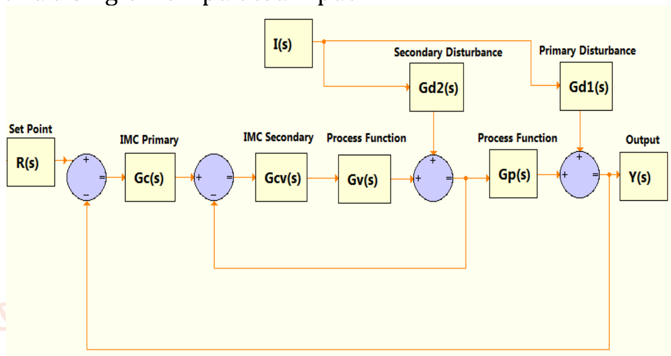

Fig.4 IMC Cascade Structure

D. Fuzzy PID Control

Fuzzy controller is a special fuzzy system that can be used as a controller component in a closed- loop system. It includes the fuzzifier, fuzzy rule base, process knowledge and FL rules, fuzzy interference engine and de-fuzzifier. The fuzzifier is the plant to fuzzy logic system interface and performs a mapping from real-valued variables into fuzzy variables. The fuzzy rule base consists of a collection of fuzzy rules. The knowledge base contains the experienced knowledge of the flow process station. Data base contains the membership function of every linguistic variable.

III. DEVELOPMENT OF VARIOUS CONTROLLERS USING LabVIEW

The author has developed VI in LabVIEW for the assessment of performance of various controllers in boiler drum level control. Three different controller i.e. feedback controller, feed forward controller and cascade controller has been applied in the system.

A. Ziegler-Nichols Method

This is the simplest method to calculate the parameters of PID. By applying this method, the PID parameters obtained are [6]

K_p= 2.1, K_i= 0.43 , K_d= 2.57

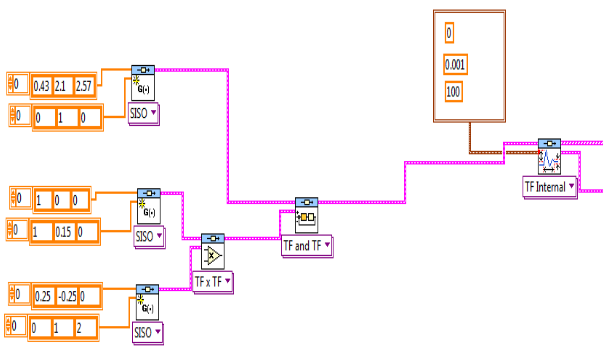

Fig.5 Transfer Function Model of Ziegler Nichols Method

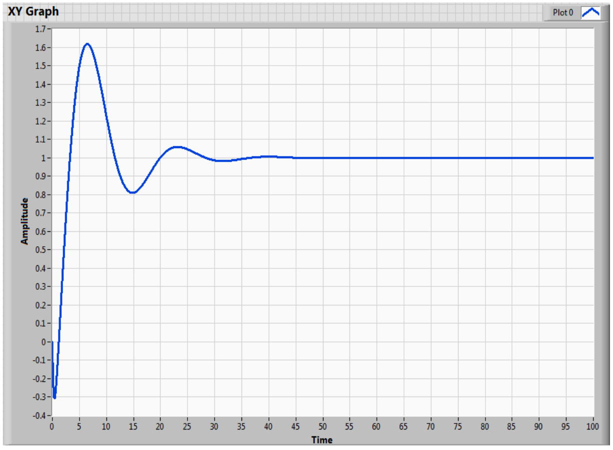

Fig.6 Response of Ziegler-Nichols Method

B. Tyreus-Luyben Method

This is another method to set the tuning values. By applying this method, PID parameters obtained are [6] as follows
K_p= 1.59, K_i= 0.073, K_d= 2.47

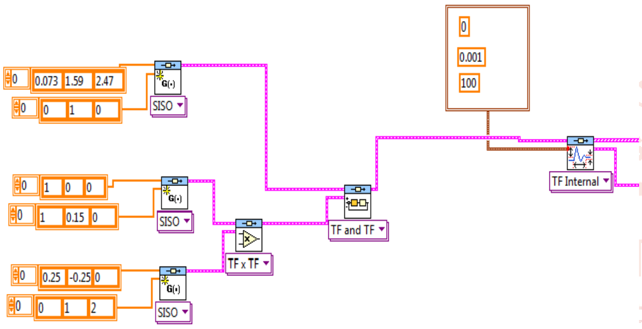

Fig.7 Transfer Function Model of Tyreus-Luyben Method

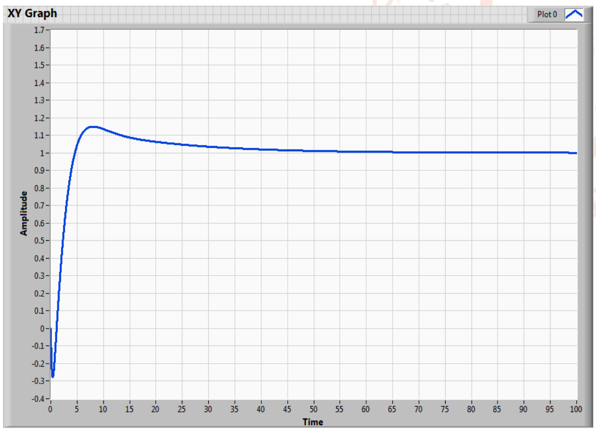

Fig.8 Response of Tyreus-Luyben Method

C. Internal Model Control (IMC)

In this process, following process model is considered and correspondingly the controller output is calculated.

$$Gp(s)=\frac{0.25(-s+1)}{s(2s+1)(0.15s+1)} \qquad 1$$

$$Q(s)=\frac{4s(2s+1)(0.15s+1)}{(s+1)(\lambda s+1)^2} \qquad 2$$

$$Gc(s)=\frac{Q(s)}{1-Gp(s)*Q(s))} \qquad 3$$

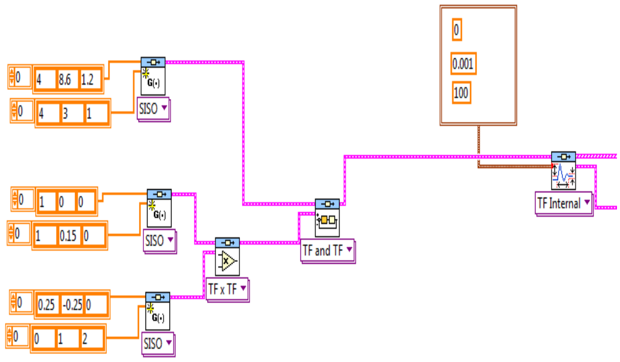

Fig.9 Transfer Function Model of IMC

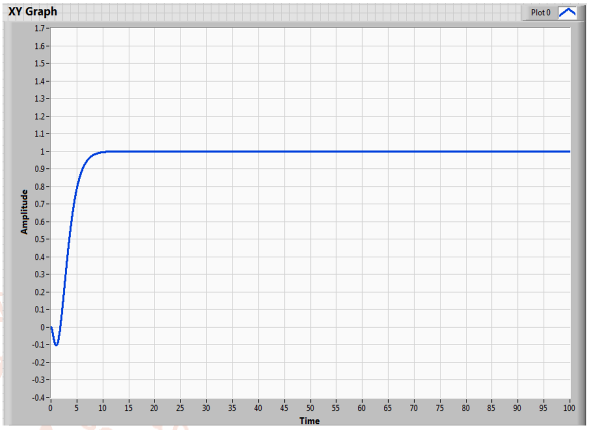

Fig.10 Response of IMC

When steam disturbance is added in the system, than single feedback controller is not enough to control the whole process. So, a feed forward controller is added which removes this disturbances before it enter into the boiler plant. Feed-forward control avoids the slowness of feedback control system. To calculate the parameter of controller for steam disturbances, following calculation have been taken.

$$Gp(s)=\frac{0.25(-s+1)}{s(2s+1)(0.15s+1)} \qquad 4$$

$$Gd(s)=\frac{-0.25(-s+1)}{s(2s+1)} \qquad 5$$

$$Gcf(s)=-\frac{Gd(s)}{Gp(s)} \qquad 6$$

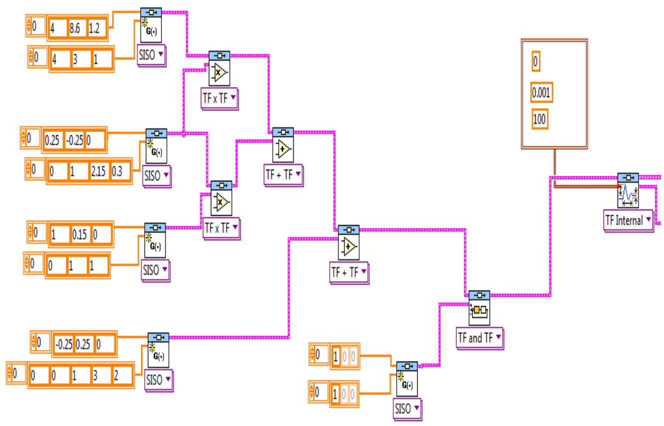

Fig.11 Transfer Function Model of FeedForward IMC

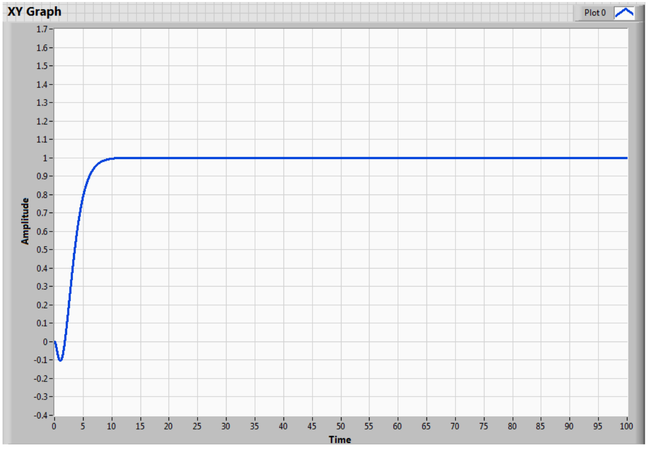

Fig.12 Response of FeedForward IMC

To make the system fast, one more parameter is added here is flow of water. To control this parameter, cascade control system is designed. Cascade Control uses the output of the primary controller to manipulate the set point of the secondary controller as a final control element.

$$G_{cv}(s)=\frac{0.47s+6.8}{s} \qquad 7$$

Where, $G_{cv}(s)$ is the flow controller of the secondary loop of cascade system.

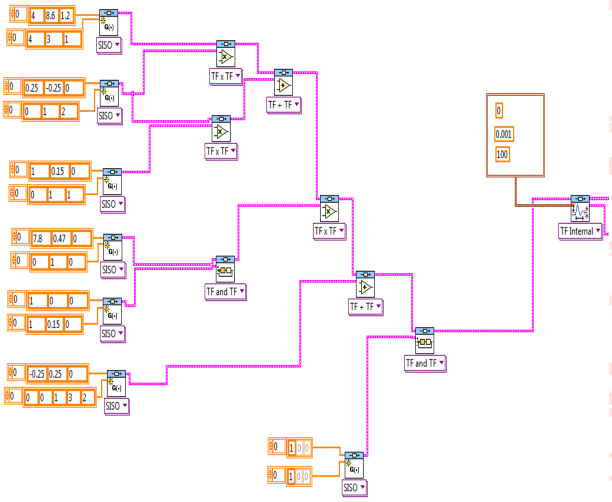

Fig.13 Transfer Function Model of Cascade IMC

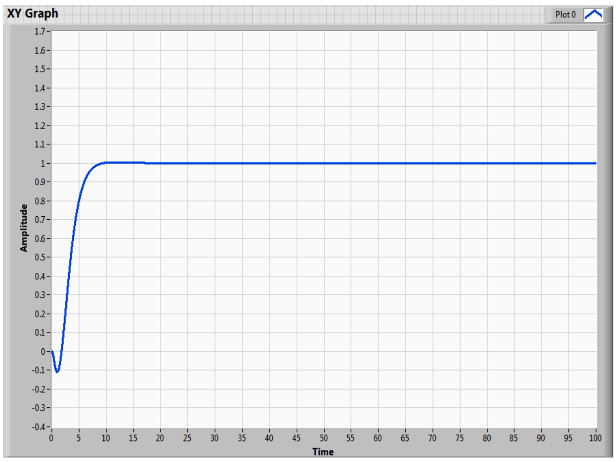

Fig.14 Response of Cascade IMC

D. Fuzzy PID Control

Fuzzy controller works as primary controller and IMC controller works as secondary controller. Different fuzzy rules have been applied to obtain various responses. The inputs are the error and the error rate. The outputs are the K_p, K_i and K_d values. It has members as Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (ZO), Positive Small (PS), Positive Medium (PM) and Positive Big (PB). Range is taken from -1 to 1.

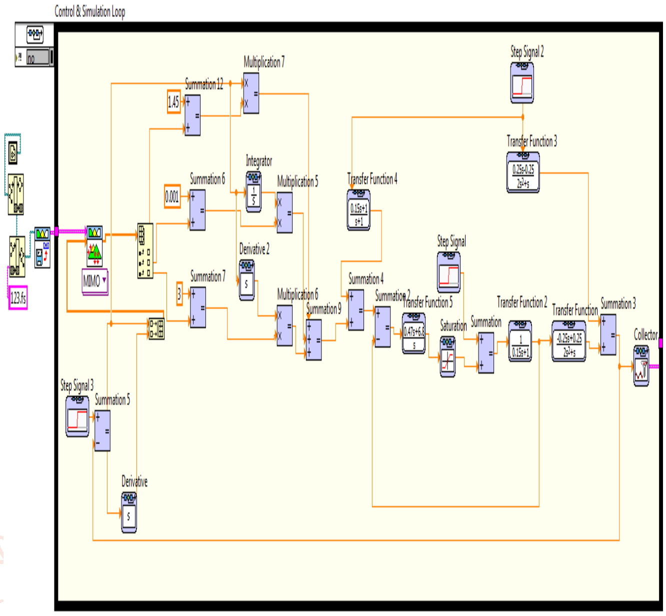

Fig.15 Block Diagram of Fuzzy PID Control

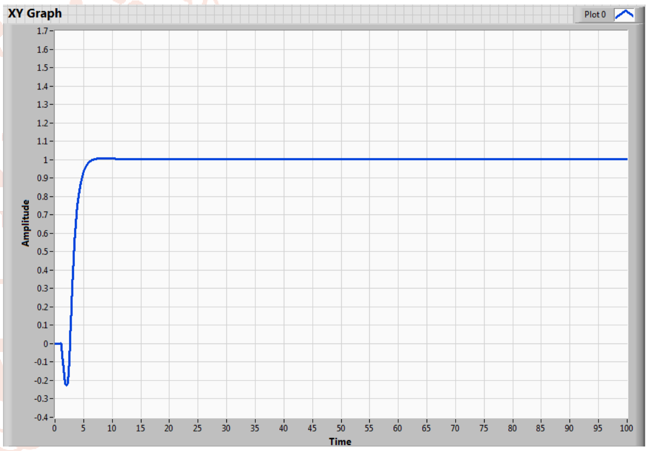

Fig.16 Response of Fuzzy PID Control

IV. COMPARISION OF BOILER PERFORMANCE

Table.3 Comparison of Boiler Performance Through Different Controllers

	Tr	Ts	%Mp	Pk
ZN	1.631	34.32	61.74	1.617
TL	2.569	51.60	14.899	1.149
IMCFB	3.923	9.146	0	1
IMCFF	3.924	9.155	0	1.0003
IMCC	3.818	8.384	0.356	1.0035
FPID	2.145	7.715	0.633	1.0063

V. CONCLUSION

In this analysis, it has seen that more accurate result has been obtained using Fuzzy PID controller. The response of the IMC based cascade PID controller is very close to fuzzy PID control method. The use of IMC based PID controller improves the performance to great extent than both of these Zeigler-Nichol and Tyreus-Luyben PID tuning techniques. Settling time, rise time peak time and peak overshoot in case of Fuzzy PID controller is less than other methods. When the plant response is changing with time, or there is uncertainty, the IMC method is preferable. IMC based PID controller can adjust the control action before a change in the output set point actually occurs. Hence, from the above data, the investigator concludes that the Fuzzy PID method is better than other PID controller techniques.

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