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Three Element Boiler Drum Level Control using Cascade Controller

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Abstract: This paper represents an approach for controlling a very crucial parameter of boiler i.e. level of the boiler drum using PID controller. In thermal power plant, the use of boiler unit which produces steam helps to rotate the turbine to produce electricity. The boiler unit consists of boiler drum that converts feed water into steam. The three types of boiler drum system are single element boiler drum, two element boiler drum and three element boiler drum. The three element boiler drum is most commonly used in thermal plant. Cascade PID method is used with feed forward and feedback strategy is used to control two element drum level. Besides this paper is also describes the modeling of the process for level control and implemented it in Simulink. Hardware model has also been developed and proved open loop validation for theoretically derived model & practical model, further practical and simulation responses are compared with respect to rise time, settling time and maximum peak overshoot.
Keywords: Drum level, Cascade PID technique; Feed forward – feedback control strategy, Modeling.

I. INTRODUCTION

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. The functions of this control module can be broken down into the following Operator adjustment of the set point for drum level. Compensation for the *shrink* & *swell* effects. Automatic control of drum level. Manual control of the feed water valve. Bumpless transfer between auto and manual modes. Indication of drum level and steam flow. Indication of feed water valve position and feed water flow. Absolute/deviation alarms for drum level. The most basic and pervasive control algorithm used in the feedback control is the Proportional Integral and Derivative (PID) control algorithm.

II. BOILER DRUM LEVEL CONTROL

Boiler drum level control is critical for the protection of plant and safety of equipment. The purpose of the drum level controller is to bring the drum level up to the given set point and maintain the level at constant steam load. An intense decrease in this level may expose boiler tubes, allowing them to become overheated and damaged. An increase in this level may cause interference with the process of separating moisture from steam within the drum, thus the efficiency of the boiler reduces and carrying moisture into the turbine [2]. Typically, there are three strategies used to control drum level. With each successive strategy, a refinement of the previous control strategy has been taken place. For extent of the load change requirements, the control strategy depends on the measurement and control equipment. The three main options available for drum level control are discussed below:

A. Single Element Drum Level Control

The single element control is the simplest method for boiler drum level control system. It is least effective form of drum level control which requires a measurement of drum water level and feed water control valve. It is mainly recommended for boilers with modest change requirement and relatively constant feed water condition. The process variable coming from the drum level transmitter is compared to a set point and the difference is a deviation value. This signal is given to the controller which generates corrective action output. The output is then passed to the boiler feed water valve, which adjusts the level of feed water flow into the

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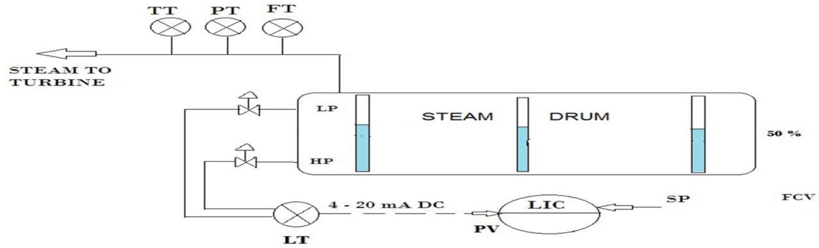
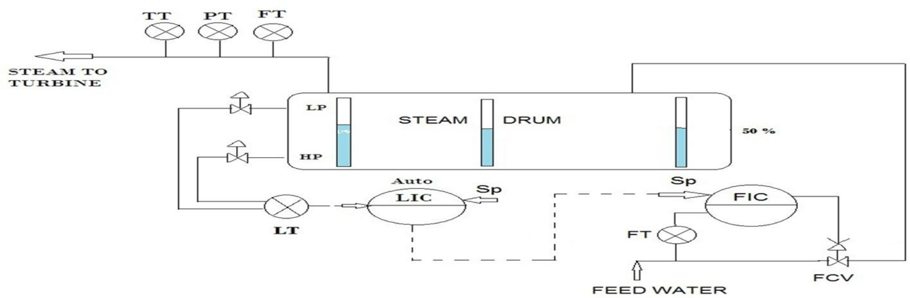
boiler drum.



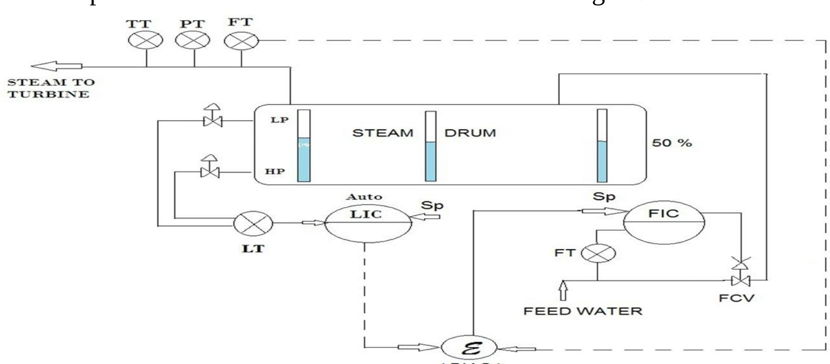
B. Two Element Drum Level Control

A two-element system can do good job under most operating conditions. Two-element control involves adding the steam flow as a feed forward signal to the feed-water valve . Two-element control is primarily used on intermediate-size boilers, in which volumes and capacities of the steam and water system would make the simple total level control inadequate because of “swell.” Total level control is undesirable when it is detected by sensors that are insensitive to density variations, such as the conductivity type. Displacement and Differential pressure type transmitter sensors are preferred from this perspective because they respond to hydrostatic pressure. Smaller boilers, in which load changes may be rapid, frequent, or of large magnitude, will also require the two-element system.



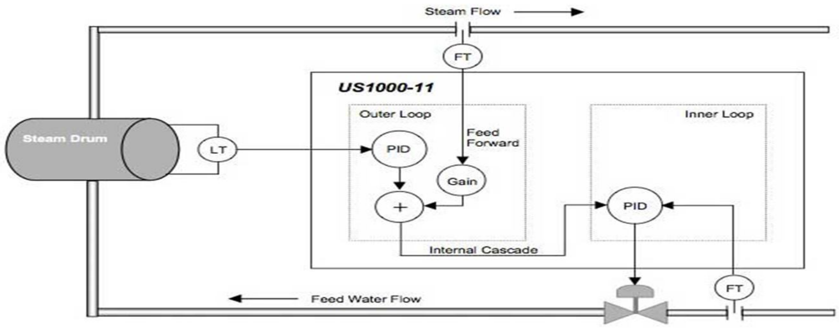
C. Three Element Drum Level Control

This control system is ideally suited where a boiler plant consists of multiple boilers and multiple feed water pumps or feed water valve has variation in pressure or flow. It requires the measurement of drum level, steam flow rate, feed water flow rate and feed water control valve. By using cascade control mechanism level element act as a primary loop and flow element act as a secondary loop and steam flow element act as a feed forward controller. Level element and steam flow element mainly correct for unmeasured disturbances within the system such as boiler blow down. Feed water flow element responds rapidly to variations in feed water demand either from the feed water pressure and steam flow rate of feed forward signal.



D. Cascade PID Controller

A Proportional-Integral-Derivative (PID) controller is a general feedback control loop mechanism widely used in industrial process control systems. A PID controller corrects the error between a measured process variable and the desired set point by calculating the value of error. The corrective action can adjust the process rapidly to keep the error minimal.



The process function, valve function and disturbance function is shown below.

Gp(s)= [0.25(-s+1)] / [s(2s+1)] (1)
Gv(s) = 1/[0.15s+1] (2)
Gd(s)=[-0.25(-s+1)]/ [s(s+1)(2s+1)] (3)

Following are the process used to determine the PID gain parameter:
1) Ziegler–Nichols Method : This method is introduced by John G. Ziegler and Nathaniel B. Nichols [8]. In this method, the Ki and Kd gains are first set to zero. The Kp gain is increased until it reaches the ultimate gain Ku, at which the output of the loop starts to oscillate [4]. Ku is found to be 3.51, Pu is 9.8. Ku and the oscillation period Pu are used to set the gains as shown in Table 1.

Ziegler-Nichol Control Type	Kp	Ki	Kd
PID	0.76	0.0010	1.2

2) Tyreus-Luyben Method: This method is introduced by Tyreus-Luyen. In this method, the Ki and Kd gains are first set to zero. The P gain is increased until it reaches the ultimate gain Ku, at which the output of the loop starts to oscillate [4]. Ku and the oscillation period Pu are used to set the gains as shown in Table 2. The Z-L and T-L Matlab Simulink Model and the response of the two conventional PID controllers shown in Table 2.

Tyreus –Luyben Control Type	Kp	Ki	Kd
PID	1.59	0.073	2.47

III. SIMULINK MODEL FOR BOILER DRUM

The Figure 4.1 represent boiler drum level control for setpoint=450cm using single element control ,Where the settling time obtained as 23.1(sec) , rise time 13.4(sec), peak response 15.5 (sec)

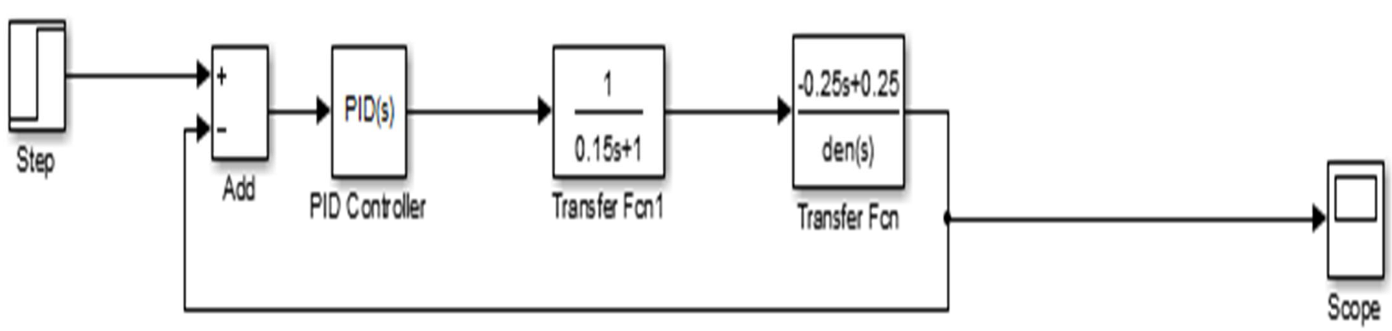


Figure 4.1 single element boiler drum level control

In Figure 4.2, The Blue Line Represent the setpoint for the single element boiler drum level control

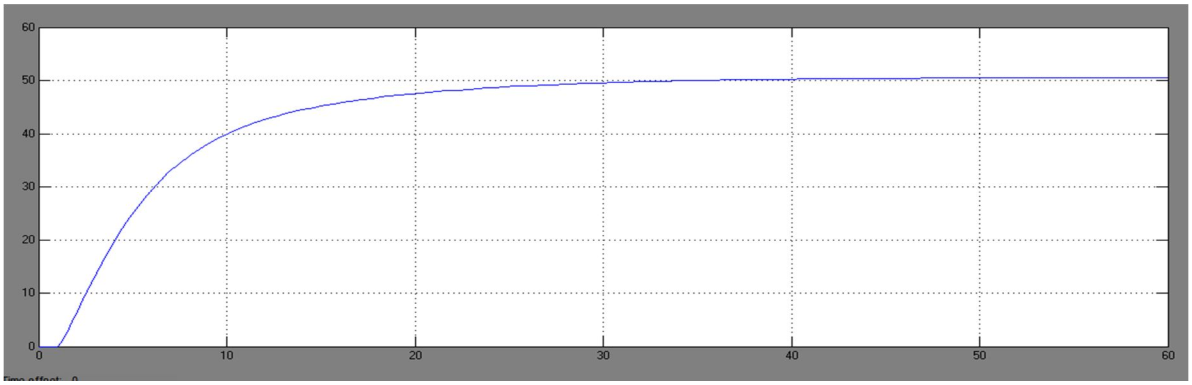


Figure 4.2 RESPONSE FOR SINGLE ELEMENT BOILER DRUM LEVEL CONTROL

The Figure 4.3 represent boiler drum level control for setpoint=50cm using single element control ,Where the settling time obtained as 20.1(sec) , rise time 10.4(sec), peak response 10.5 (sec)

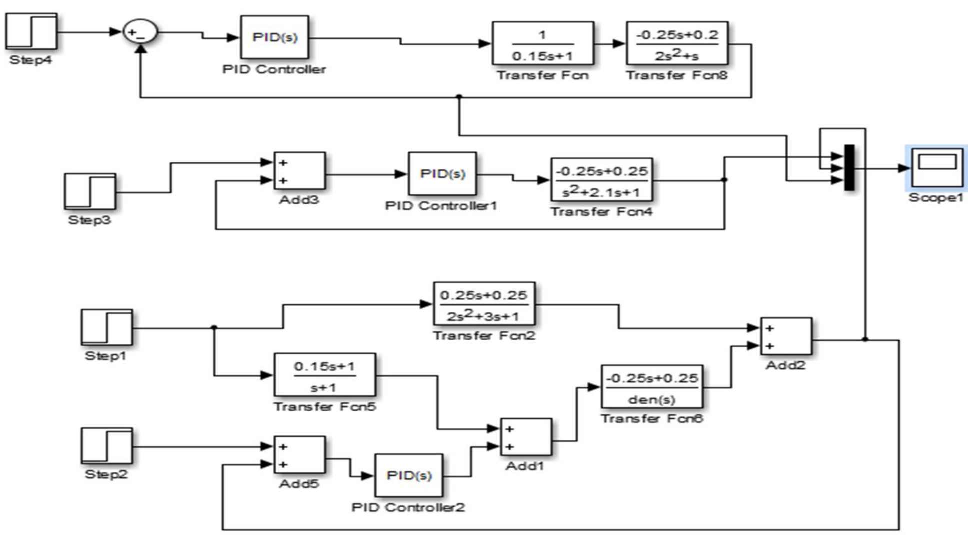


figure 4.3 three element boiler drum level control

In Figure 4.4, The Blue Line Represent the control valve function for the single element boiler drum level control then green and red represent the level and steam flow of the system.

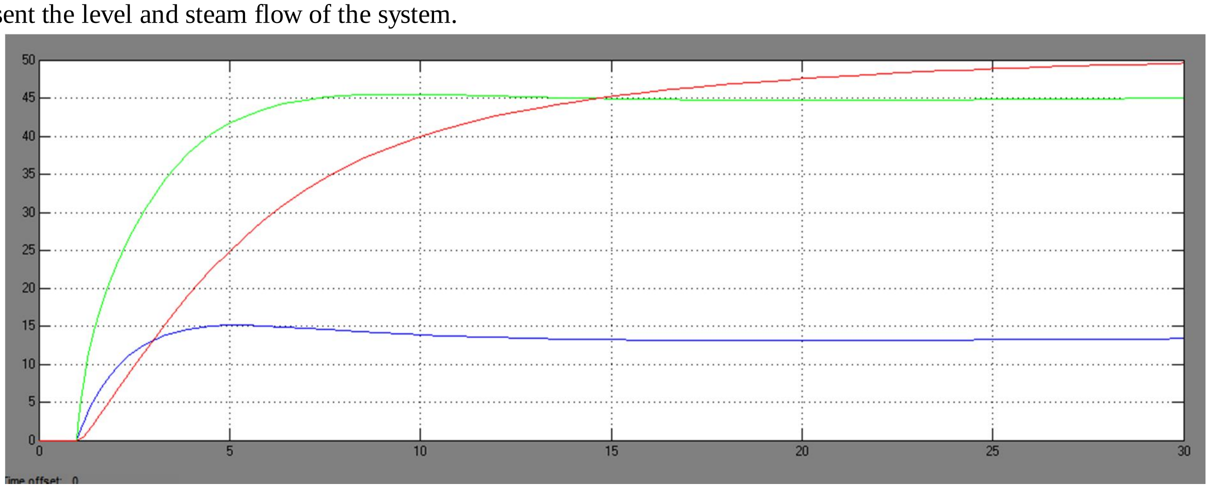


Figure 4.4 responsefor three element boiler drum level control

IV. CONCLUSION

This paper presents a novel design method by introducing an intelligent model to achieve the expected output. The comparison between the methods are shown. Through the simulation all the controllers perform an efficient search to obtain an optimal solution that achieve better performance criterion with respect to rise time, settling time, percentage of overshoot. The Feed forward controller improves the performance to great extent than both of these Zeigler-Nichol and Tyreus-Luyben PID tuning techniques.

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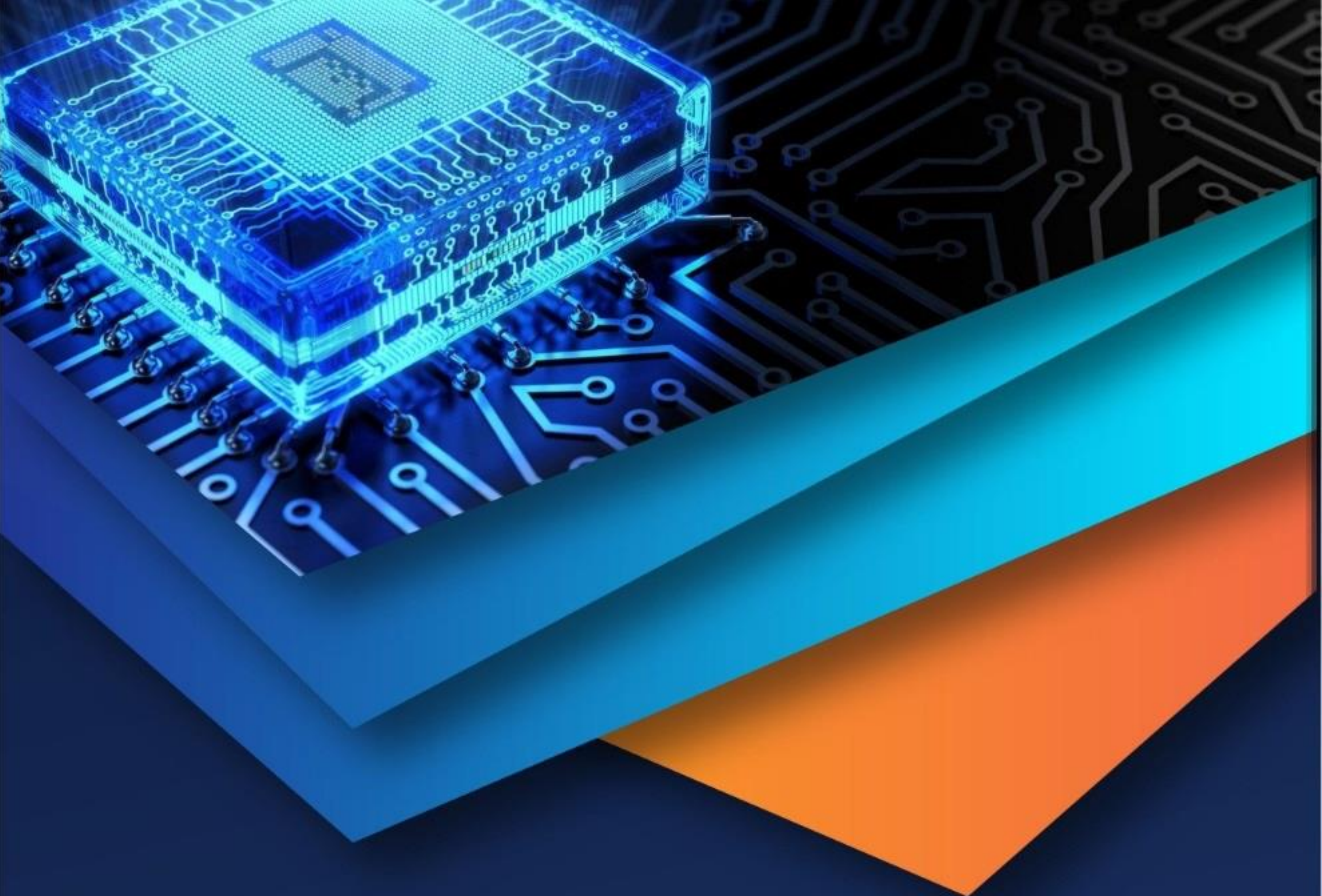

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