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Thermal Power Station Boiler Drum Level Control Using Fuzzy Logic

Kavitha B

Lecturer, Department of Electronics and Communication Engineering, IRT Polytechnic College, Chennai, India

ABSTRACT - Steam pressure is the source for generation of power in thermal power plants. In the boilers, water is converted into steam. To run the boiler safely a balance in water and steam is necessary. For instant storing of water a device called boiler drum is used. The steam is collected by heating of water tubes. Hence to produce continuous power generation it requires a balanced combination of water and steam. When there is no process disturbance the PID Controller works to the satisfactory level. In case of disturbances the performance of the PID controller is not satisfactory due to lack of proper controller gains. The proposed approach is used to observe the PID controller and collect data, which is used to gain knowledge about the process. An intelligent fuzzy logic control technique was developed with the help of the knowledge gained. The results prove that the performance of Fuzzy Logic Control perform is better than the PID controller scheme during the process disturbance.

KEYWORDS: Boiler Drum, Fuzzy, Steam, Water, Set Point

I. INTRODUCTION

1. Boiler Description

The water drum, or steam drum, is an integral part of the boiler's design. This part serves for the following purposes;

a. Provide space for holding the boiling water and also provide enough water space to allow for good thermal mixing of the cooler bottom drum water with the hotter surface interface water, and
b. Provide surface area and volume for the efficient release of the steam bubbles from the boiler water.
c. The surface area and volume of the vapor space in the boiler drum is critical to the efficient separation of the steam bubbles from the water. Precise area is very much required as a very small area may result in wasted heat and drum water carry-over due to excessive surface tension and high velocities, and more area is a mere waste of materials and labor to construct the vessel.

The boiler drum also provides a logical location for:

a. Addition of feed water
b. Addition of chemical water treatment and
c. Surface blow down, which helps reduce the surface tension of the water/steam interface to allow better steam release. Because all of these tasks involve the removal and addition of some mass (water or steam) the water/steam interface is always in a state of flux. Maintaining a stable interface level is critical to the safe and efficient operation of the boiler.

High water levels raise steam exit velocities and result in priming or boiler water carryover in to the distribution system. Priming results in wet dirty steam while carry-over can result in dangerous water hammer and pipe or equipment damage. Low water levels affect the internal thermal recirculation of the boiler water resulting in cold spots in the boiler water and steam collapse. This lack of circulation also reduces the effectiveness of the chemical water treatment and can cause precipitation of the chemicals as chemical salts or foams.

A boiler is comprised of two basic systems. One system is the steam water system also called the waterside of the boiler. In the waterside, water is introduced and heated by transference through the water tubes, converted to steam, and leaves the system as steam. Boilers must maintain a chemical balance. The manner in which this is done can interact with the feed water control system. The amount of blow down must be considered in the feed water control scheme, especially if the blow down is continuous. Often, the blow down flow is divided by the concentration ratio times the

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feed water flow. Continuous blow down is the common method for controlling the chemical concentration. On large boilers this may be done automatically by measuring the boiler water conductivity to control the blow down rate. The blow down rate may also be achieved by combining the conductivity with ratio control of blow down, rationing blow down to feed water flow.

2. Drum Level Control

The Two-Element Drum Level Control is suitable for processes with moderate load swings and can be used on any size boiler. The Two-Element Drum Level Control uses two variables, drum level and steam flow to manipulate the feed water control valve. Steam flow load changes are fed forward to the feed water control valve providing an initial correction for the load changes. The steam flow range and feed water flow range are matched so that a one pound change in steam flow results in a one pound change in feed water flow. The summer combines the steam flow signal with the feedback action of the drum level controller which makes trim adjustments in feed water flow, as required, to compensate for unmeasured blow down losses and steam flow measurement errors. The UDC 3500 can be placed into Manual mode to permit manual control of the feed water valve.

In two-element control, steam flow is measured along with boiler drum level. The steam flow signal is used in a feed forward control loop to anticipate the need for an increase in feed water to maintain a constant drum level. This strategy requires the differential pressure across the feed water control valve to remain constant as well as the control valve signal vs. flow profile. Boilers with moderate load changes can usually be controlled with this strategy.

3. PID Controller

A proportional–integral–derivative controller (PID Controller) is a generic control loop feedback mechanism widely used in industrial control systems. A PID controller attempts to correct the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly.

The PID controller calculation (algorithm) involves three separate parameters; the Proportional, the Integral and Derivative values. The Proportional value determines the reaction to the current error, the Integral value determines the reaction based on the sum of recent errors, and the Derivative value determines the reaction to the rate at which the error has been changing. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve or the power supply of a heating element.

By "tuning" the three constants in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability.

Some applications may require using only one or two modes to provide the appropriate system control. This is achieved by setting the gain of undesired control outputs to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are particularly common, since derivative action is very sensitive to measurement noise, and the absence of an integral value may prevent the system from reaching its target value due to the control action.

4. PID Control Theory

This section describes the ideal parallel or non-interacting form of the PID controller. For other forms please see the Section "Alternative notation and PID forms". The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). Hence:

$$\mathrm{MV(t)} = P_{\mathrm{out}} + I_{\mathrm{out}} + D_{\mathrm{out}}$$

where P_{out}, I_{out}, and D_{out} are the contributions to the output from the PID controller from each of the three terms, i.e. proportional, integral and derivative.

i. Proportional Term

The proportional term makes a change to the output that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain. The proportional term is given by:

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$$P_{\mathrm{out}} = K_p\,e(t)$$

where P_{out}: Proportional output, K_p: Proportional Gain, a tuning parameter , e: Error = $SP - PV$ and t: **Time** or instantaneous time (the present)

ii. Integral Term

The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. Summing the instantaneous error over time (integrating the error) gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain and added to the controller output. The magnitude of the contribution of the integral term to the overall control action is determined by the integral gain, K_i. The integral term is given by*:*

$$I_{out} = K_i \int_0^t e(\tau)\,d\tau$$

where I_{out}: Integral output , K_i: Integral Gain, a tuning parameter , e: Error = $SP - PV$ and τ: Time in the past contributing to the integral response.

iii. Derivative Term

The rate of change of the process error is calculated by determining the slope of the error over time (i.e. its first derivative with respect to time) and multiplying this rate of change by the derivative gain K_d. The magnitude of the contribution of the derivative term to the overall control action is termed the derivative gain, K_D.The derivative term is given by:

$$D_{\mathrm{out}} = K_d \frac{de}{dt}$$

where D_{out}: Derivative output , K_d: Derivative Gain, a tuning parameter , e: Error = $SP - PV$ and t: Time or instantaneous time (the present).

The output from the three terms, the proportional, the integral and the derivative terms are summed to calculate the output of the PID controller. Defining $u(t)$ as the controller output, the final form of the PID algorithm is:

$$\mathrm{u(t)} = \mathrm{MV(t)} = K_p e(t) + K_i \int_0^t e(\tau)\,d\tau + K_d \frac{de}{dt}$$

The tuning parameters are:

a. K_p: Proportional Gain - Larger Kp typically means faster response since the larger the error, the larger the Proportional term compensation. An excessively large proportional gain will lead to process instability and oscillation.

b. K_i: Integral Gain - Larger Ki implies steady state errors are eliminated quicker. The trade-off is larger overshoot: any negative error integrated during transient response must be integrated away by positive error before we reach steady state.

c. K_d: Derivative Gain - Larger Kd decreases overshoot, but slows down transient response and may lead to instability due to signal noise amplification in the differentiation of the error.

The drawback of using PID controller alone are, in the PI band control over shoot oscillation will be more, Time taken to reach the steady state is more, Gain and efficiency is low and Level control is maintained approximately.

II. LITERATURE SURVEY

Mamdani.E.H [1] proposed that fuzzy controller has a considerable advantage in rise time, settling time and overshoot respect to PID controller when the servo system encounters with nonlinear features like saturation and friction.

Van Landingham.V.H [2] describe that an intelligent control scheme such as FLC gives better performance in rejecting process disturbances when compared to 3-element PID control scheme. Astrom.K.J [3] describes some features that may be included in the next generation of PID controllers.

Franksen, O. I [4] provide a unification of the theory of finite polyvalent logic the conventional axiomatic approach is substituted by an alternative group- theoretical formulation. Among the systems treated, besides Boolean or

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divalent logic, are those of Kleene, Bochvar, Post, and Lukasiewicz. APL is adopted as the mathematical notation throughout.

Jantzen, J [5][1995] found promising results from applying an array-based approach to two-valued logic suggests its application to fuzzy logic. The idea is to limit the domain of truth-values to a discrete, finite domain, such that a logical relationship can be evaluated by an exhaustive test of all possible combinations of truth-values. The objective is to identify and describe the choices based on an international standard which is underway. The paper can be used as an introduction to commercial software packages for fuzzy controller design.

Jantzen, J [6] [1998] The paper presents a study of the topic from an engineer's viewpoint. As an example 31 logical sentences valid in two-valued logic were tested in three-valued logic using the nested interactive array language, Nial. Out of these, 24 turned out to be valid in a three-valued extension based on the well-known S∗ implication operator, also called “Gödel's implication operator”. Applications to automated approximate reasoning and fuzzy control are also illustrated.

Kiszka. J.B [7] presents an on-line identification algorithm for fuzzy systems which can on-line update the fuzzy model.

III. PROPOSED SYSTEM

Fuzzy logic is other class of artificial intelligence, but its history and applications are more recent than those of expert system. Human thinking doesn’t always follow crisp “YES/NO” logic, but is often vague, qualitative, uncertain, imprecise or fuzzy in nature, “Knowledge-based or rule-based systems, If-Then rules”.

A fuzzy set can be defined mathematically by assigning to each possible individual in the universe of discourse, a value representing its grade of membership in the fuzzy set. This grand corresponds to the degree to which that individual is similar or compatible with the concept representing by the fuzzy set. In other words, fuzzy sets support a flexible sensing of membership of elements to a set. Fuzzy set A, is said to be subset of B if $\mu A(x) \leq \mu B(x)$.

Hardware required for implementation of the proposed are differential pressure transmitter, relay, pneumatic valve actuator, boiler drum, ADC, interface, programmed computer, DAC, power supply unit, valve driving circuit.

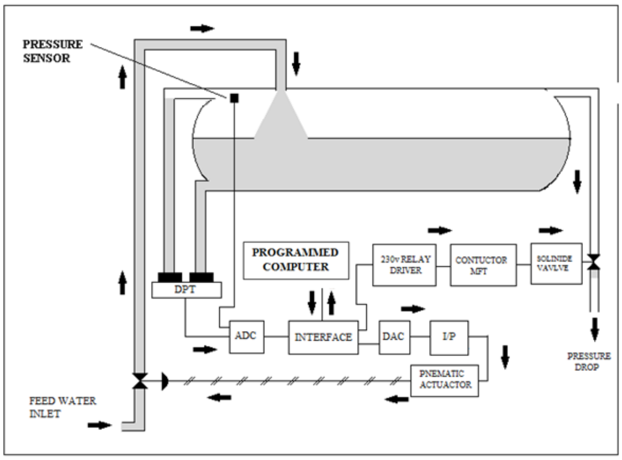

Figure - 1 Block Diagram of Drum Level Controller

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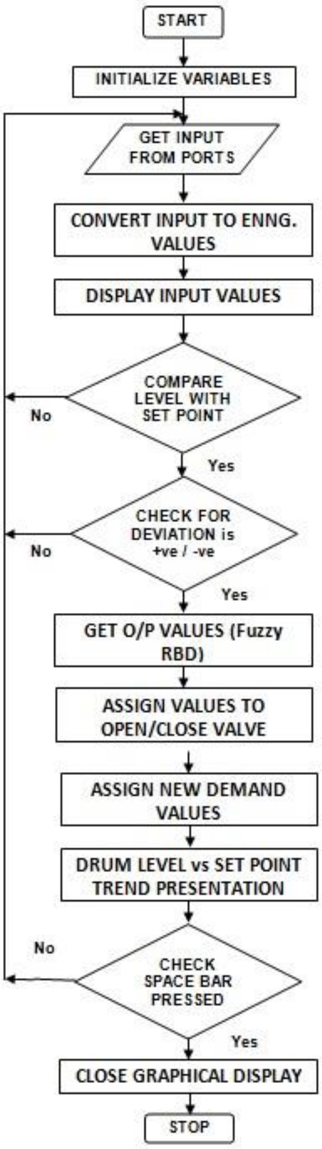

Figure -2 Flow chart of Process

IV. SIMULATION AND RESULTS

Simulation is carried out using the C program in graphics mode and the results are displayed in graphics pattern. The input values are converted into engineering values and output is obtained with the help of Fuzzy RBD and Fuzzy output display.

Boiler Drum level is obtained is based on reference value of set point and one of set point value is given figure. The drum level output wave is shown in the figure with set point -20.

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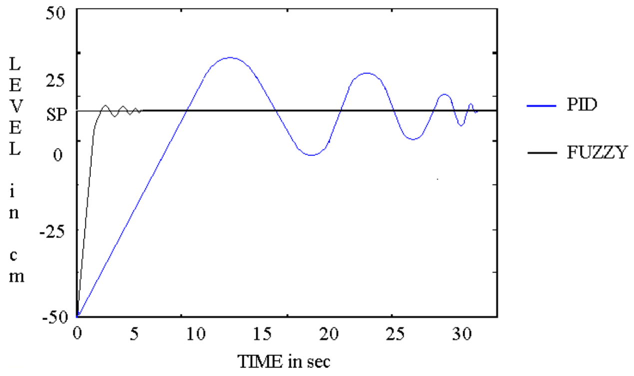

Figure – 3 Comparison between PID & Fuzzy

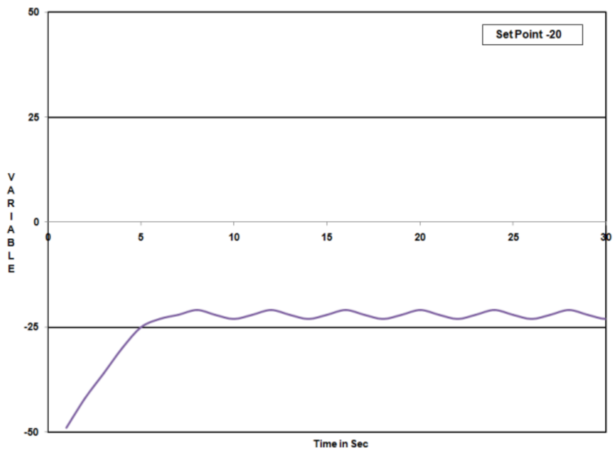

Figure – 4 Output Response of Drum Level

The level is maintained by the set point and level is controlled without any oscillation or overshoot and proves that inclusion of fuzzy maintains the level of boiler drum and increase in efficiency.

V. Conclusion

A balanced combination of water and steam must be present in the boiler drum to produce continuous power generation. PID controller works satisfactorily in the absence of any process disturbance. When there is a significant disturbance during process, PID controller does not perform well because of lack of knowledge of proper controller gains to cope with such disturbances. Inevitably over time and use, PID controllers get detuned. Thus the implementation of Fuzzy logic proves to maintain the boiler drum level, hence protect the boiler and also increase in efficiency. It can further be enhanced by using OPC (open platform communication) and MATLAB.

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