International Journal of Scientific Research Engineering & Technology (IJSRET) ISSN: 2278–0882
EATHD-2015 Conference Proceeding, 14-15 March, 2015

A Nobel Design of Monitoring and Control of a Boiler Drum Level by Fuzzy PID Adaptive Controller Using Labview

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ABSTRACT

This paper gives a framework of supervisory control of boiler drum level system. The design and implementation of this process is done by the LabVIEW software. The data of the process variables Level from the boiler system need to be logged in a database for further analysis and supervisory control. A LabVIEW based data logging and supervisory control program simulates the process and the generated data are logged in to the database as text file with proper indication about the status of the process variable .This paper provides the knowledge about the Fuzzy Adaptive PID Controller and the various PID controller design method.

I. INTRODUCTION

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. Due to poorly understand the working principles; boilers have many serious injuries and destruction of property. It is critical for the safe operation of the boiler and the steam turbine. Too low a level may overheat boiler tubes and damage them. Too high a level may interfere with separating moisture from steam and transfers moisture into the turbine, which reduces the boiler efficiency. Various controlling mechanism are used to control the boiler system so that it works properly. To maintain the boiler drum level constant proper data monitoring and recording is required. The data can be temperature, pressure, displacement, flow, voltage, strain, current, power or any wide range of process variables. Data logging is commonly used in monitoring system where there is the need of collecting information faster than a human can possible collect the information over a period of time. It has the ability to automatically collect data on a 24 hour basis.

NI-LabVIEW-National Instrument's LabVIEW is a graphical development environment for creating flexible, measurement and control applications rapidly at minimal cost. With LabVIEW, engineers and scientists interface with real-world signals, analyse data for meaningful information and share results. LabVIEW makes development very fast and easy for all users. The main programming section of LabVIEW is a Virtual Interface (VI) and a corresponding block diagram. Programming for the VI is done using control palette which contains several controls and indicators

II. CONTROL STRATEGIES OF BOILER

II.1Three Element Control

In the process industries, to control the three elements of boiler i.e. Steam flow, drum level of water and feed water flow is required for the proper functioning of boiler. Pressure, temperature and level cannot be controlled; the only thing that can be controlled is flow.The pressure or temperature in a boiler is maintained by controlling the flow of fuel and air. Also, the level is maintained by controlling the flow of feed water. Pressure, temperature, level and other variables will increase or decrease only with a change in flow. To maintain the drum level at constant steam load, a controller has been designed to bring the drum up to the level of set point. In single-element control, only drum level measurement and a feed water control valve are required. The two-element drum level control uses two variables i.e. drum level and steam flow to manipulate the feed water control valve. The three-element drum level control uses three variables i.e. drum level, steam flow and feed water flow rate, to manipulate the feed water control valve as shown in Fig. II.1

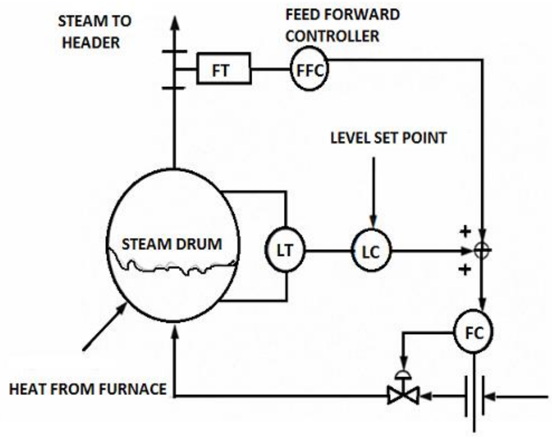

Fig.II.1 Three element boiler drum level control

II.2 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 PID controller separately calculate the three parameters i.e. the proportional, the integral, the 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 as past error. The derivative value determines the reaction based on the rate at which the error has been changing as a future error. By tuning these three constants in the PID controller algorithm, the controller can provide control action designed for specific process control requirements.

II.3 Fuzzy Adaptive PID Control

Based on the process knowledge, an intelligent control technique that is Fuzzy Adaptive PID Control is discussed. The structure of fuzzy adaptive PID controller is shown in Fig. 2.2. It mainly consists of two parts, one is the conventional PID controller and the other is fuzzy logic controller. In this work, two input and three output fuzzy adaptive PID controller is designed. The inputs are the error and the error rate (change in error) and outputs are the values of Kp, Ki and Kd. The objective is to find the fuzzy relations among Kp,Ki,Kd, error and error rate. With continuous testing, the three output parameters are adjusted so as to achieve good stability. Variable PID controller adds the output value of the fuzzy controller and default PID values.

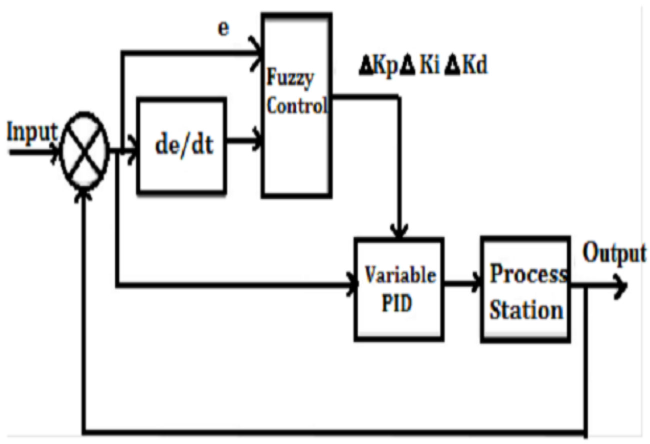

Figure II.2 Structure of Fuzzy Adaptive PID

III. DESIGN OF FUZZY ADAPTIVE PID CONTROLLER

Fuzzy controller is a special fuzzy system that can be used as a controller component in a closedloop 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 Control rules are described by the data base. The defuzzifier is the fuzzy logic system-to-plant interface and performs a mapping from fuzzy variables to real-valued variables.

III.1 Membership Function

The membership function used by fuzzy controller is the triangular membership function. The input ranges is from -1 to +1 and the fuzzy subset are Negative Big, Negative medium, Negative small, Zero, Positive small, Positive medium and Positive Big respectively termed as NB, NM, NS, ZO, PS, PM and PB. The performance of the controller depends on the quantization factor and the scaling factor.

III.2 Control Rules of the Fuzzy Controller

The control rules are designed to achieve the best performance of the fuzzy controller. In this work 49 control rules are adopted. These rules are given in the Table 3.1, 3.2 and 3.3

E \ EC	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	NS
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PM	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

Table 3.1 Ki Fuzzy Control Rule

E \ EC	NB	NM	NS	ZO	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	ZO
NS	ZO	NS	NM	NM	NS	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

Table 3.2 Kd Fuzzy Control Rule

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E \ EC	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NB	NM	NS	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	ZO	ZO	PS	PS	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

Table 3.3 Ki Fuzzy Control Rule

Using this control rules, fuzzy.fs file is created. This control rules are generated using the Fuzzy System Designer toolbox available in LabVIEW. The membership function with the mentioned fuzzy subsets and the control rules form the fuzzy controller. This .fs file is called in the simulation environment of LabVIEW as a sub VI. The inference engine used here is the Mamdani Inference engine. The technique proposed in this work has been tested on a Circuit Design and Simulation toolkit based on LabVIEW.

Fuzzy controller works as primary controller as secondary controller. Different fuzzy rules will be applied to obtain various responses.

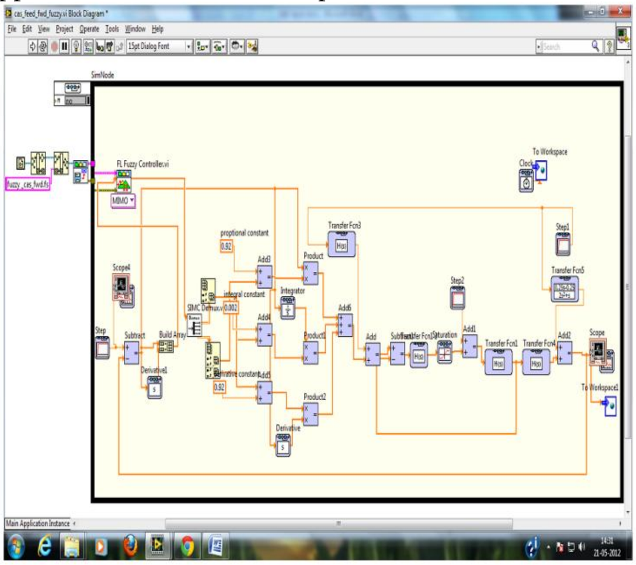

Fig.3.5 shows the membership function plots for the two input and three output variable level.

The inputs are the error and the error rate. The outputs are the Kp, Ki and Kd values. It has members as Negative Big (NB), Negative Medium (NM), Negative Small (NS), No Change (NC), Positive Small (PS), Positive Medium (PM) and Positive Big (PB). Range is taken from -1 to 1.

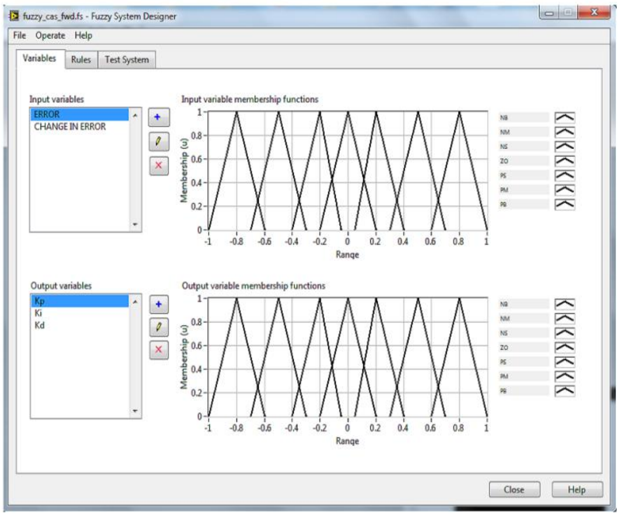

Figure 3.6 Input/output Membership Function (Using Mamdani Method)

Fig. 3.7 shows the rule based of the fuzzy logic controller for the three element control system. It consist of forty nine rule based using If-and-then rules condition for each Kp, Ki and Kd values. Total of 147 rule base is designed for Fuzzy adaptive PID controller and that file is saved as fuzzy.fs file.

Fig. 3.8 shows the responses of the Fuzzy Adaptive PID controller for the step input. The performance of the system is very fast. Its rise time and settling time is very low. So, the response of the system is rapid. This controller performance is much better than the other PID controllers

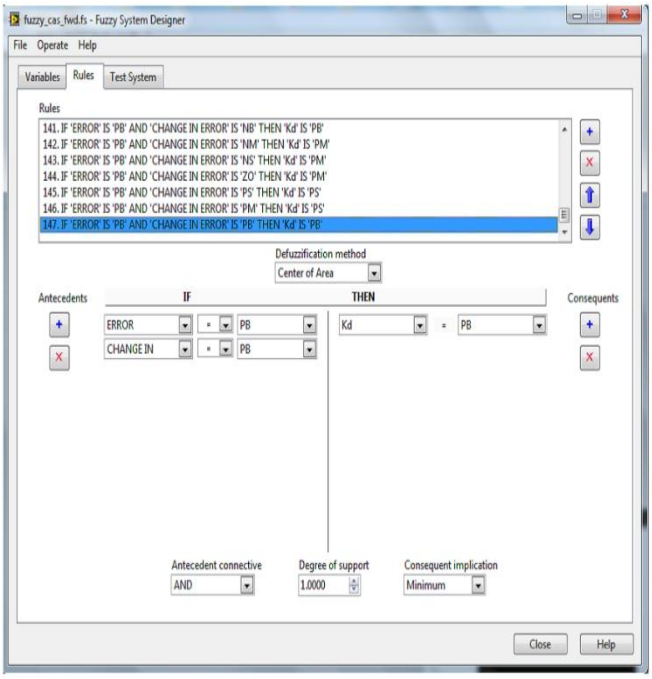

Figure 3.7 Fuzzy Rule Base

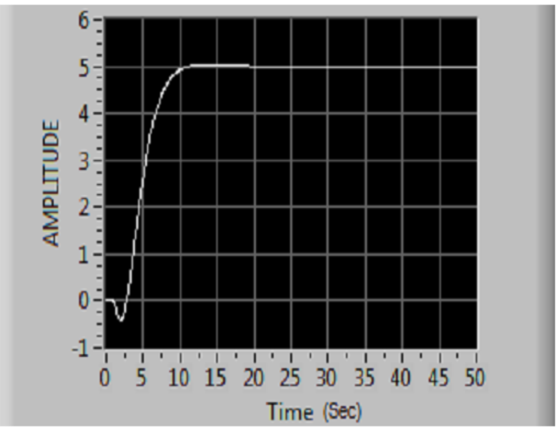

Figure 3.8 Fuzzy Adaptive PID Controller Responses With Step Input.

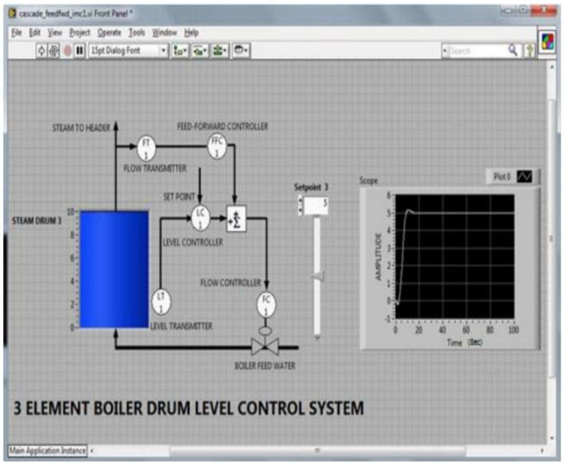

Figure 4.20 Front Panel Diagram of Three Element Boiler Level Control

IV. RESULT

Three element boiler level control has been designed using the circuit design tool kit in Lab VIEW. Fig.4.20 show the front panel diagram of PID controller of three element boiler level control in which steam flow element acts as a feed forward controller, level element acts as a primary loop and flow element act as a secondary loop in the cascade controller Table 3.4 Comparison of the Boiler Performances through Different Controller

Controller / Parameter	Ziegler Nichol	Tyreus-Luyben	IMC Feedback	IMC Feed Forward	IMC Cascade	Fuzzy Adaptive PID
Rise Time(r_t)Sec	3	4	21	17	7	12
Peak Time(p_t)Sec	6	7	-	-	11	-
Settling Time(S_t)Sec	40	50	21	17	14	12
Peak Overshoot(M_p)	60%	15%	-	-	5%	-

Table 3.4

We have seen that more accurate result has been obtained using Fuzzy Adaptive PID controller. The response of the IMC based PID controller is very close to fuzzy Adaptive 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 Adaptive controller is less than other methods.When the plant response is changing with time, or there is uncertainty we prefer IMC method IMC based PID controller can adjust the control action before a change in the output set point actually occurs. Hence, from the above data, we conclude that the Fuzzy Adaptive PID method is better than other P ID controller techniques.

V. CONCLUSIONS

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 steam flow rate feed forward signal and feed water pressure or flow fluctuations. The graph shows the unit step responses of the controller. Its rise time is very small and peak overshoot is very low. As a result, the overall performance of the controller is very fast.

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