International Journal of Recent Research in Interdisciplinary Sciences (IJRRIS)
Vol. 1, Issue 1, pp: (29-34), Month: April - June 2014, Available at: www.paperpublications.org

TUNING OF GAINS IN BASIS WEIGHT USING FUZZY CONTROLLERS

[1]Chandani Sharma, [2]Anamika Jain

[1]Research Scholar, Electronics & Communication Engg. Graphic Era University, Dehradun, Uttrakhand, India
[2]Professor, Electronics & Communication Engg. Graphic Era University, Dehradun, Uttrakhand, India

Abstract: **New generation Fuzzy Logic Controllers are based on the integration of conventional and Fuzzy controllers. India being the fastest growing market for paper globally presents an exciting industry scenario. The main requirement concerns measured and controlled variable for paper including Basis weight and moisture. This research is an effort to achieve better performance with nonlinear processes in servo applications. Three different structures on Fuzzy-P, Fuzzy-PD and Fuzzy-PD+I are studied for variable input using Simulink and Fuzzy Logic toolbox. Analysis of four scaling gains GE, GCE, GIE and GU is done to obtain most appropriate output.**

Keywords: **Fuzzy Controllers, Fuzzy-P, Fuzzy-PD, Fuzzy-PD+I, Basis Weight, Simulink.**

I. INTRODUCTION

A fuzzy controller is used to control a target system or for supervisory control. It has linguistic interpretation which can be represented using fuzzy sets, membership functions, and fuzzy rules. Real time applications involve more non linearity thus different fuzzy types are used. P-type, PD-type and PI-type fuzzy controllers are the best-known counterparts of conventional PID controller. They are used to achieve better performance with nonlinear processes.

For analyzing performance of systems a two-input single-output fuzzy logic controller is designed. The target end product of paper that needs to be controlled is known as grammage per square meter (GSM). The process as a whole has one controlled output i.e. Basis weight (B) and one manipulated input i.e. pulp flow (G) monitored by the basis weight valve opening (BWVO) at the head box.

The transfer function between input function "G(s)" to output function “B(s)” is given by:

$$\frac{B(s)}{G(s)} = \exp(-144*s)\ \frac{5.12}{105\,s + 1} \quad \ldots\ldots\ldots\ldots\ldots (1.1)$$

where G(s) = Pulp Flow at head box and B(s) = Basis weight per square meter

The system uses exp (-144*s) as transportation Lag and τ as time constant of the system. 5.12=K, a constant that represents the dimensional conversion factor based on equipments involved in the system.

The FLC is used to adjust the basis weight valve opening according to the changing values of the basis weight set point. The input variables are the error (e) and change in error (che), and the output variable is basis weight valve opening (bwvo).Fuzzy controller gains needs to be monitored and integral or derivative of the error may be useful inputs as well.

The basic structure and process dynamics for FP, FPD and FPD+I are described below,

The fuzzy P (FP) two gains GE and GU are given by relation.

$$GE * GU = K_P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.2)$$

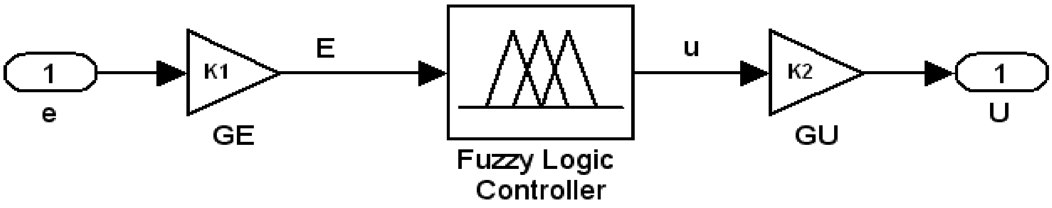

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Figure 1.1 Fuzzy-Proportional Controller (FP)

The fuzzy Proportional-derivative (FPD) uses derivative of gain related in the following way:

$GE*GU=K_P$ ………………………… (1.3)

And

$GCE/GE=\tau_D$………………………… (1.4) where $ce = e_t - e_{t-1}$

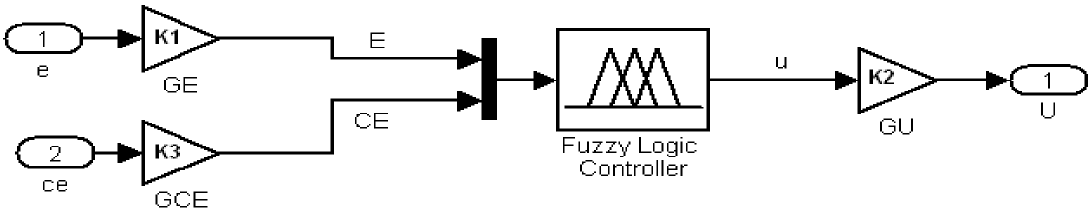

Figure 1.2 Fuzzy-PD Controller (FPD)

The fuzzy Proportional-derivative with integral (FPD+I) always return to zero in steady state with gains as,

$GE*GU=K_P$………………………… (1.5)

$GCE/GE=\tau_D$……………………….... (1.6) and

$GI/GE=1/\tau_I$………………………….. (1.7)

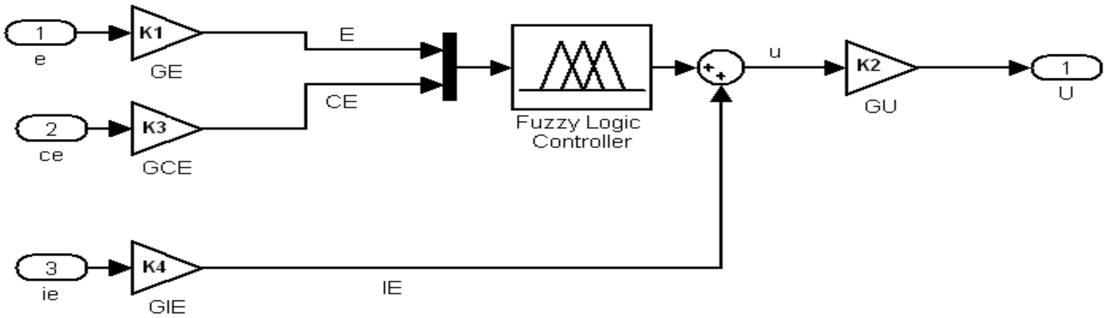

Figure 1.3 Fuzzy PD+I Controller (FPD+I)

The values of these normalization gains GE, GCE, GIE are responsible for the proportional constant (K_P), the derivative rate (τ_D) and the reset rate (τ_I). Here the work is to analyze the effect of changing gains on the response of the system.

II. SERVO MODEL FOR VARYING INPUT USING FLC

A Servo model using Simulink, Fig 1.4 is developed which has a Fuzzy Logic Controller with a rule viewer, two summing elements, a process (Gb), a multiplexer, a derivative element, a input block from where the different types of inputs can be given, four gain elements representing the scaling gains as GE, GCE, GIE and GU, and finally an output block.

The simulation is done for variable inputs i.e. the data for the reference inputs is collected from the mill where online sensors are incorporated and the value of the inputs i.e. the basis weight continuously changes according to the demand. This data has been saved in the m-file of Matlab and is collected from the workspace from where it is given as the input to model of Fig 1.4.

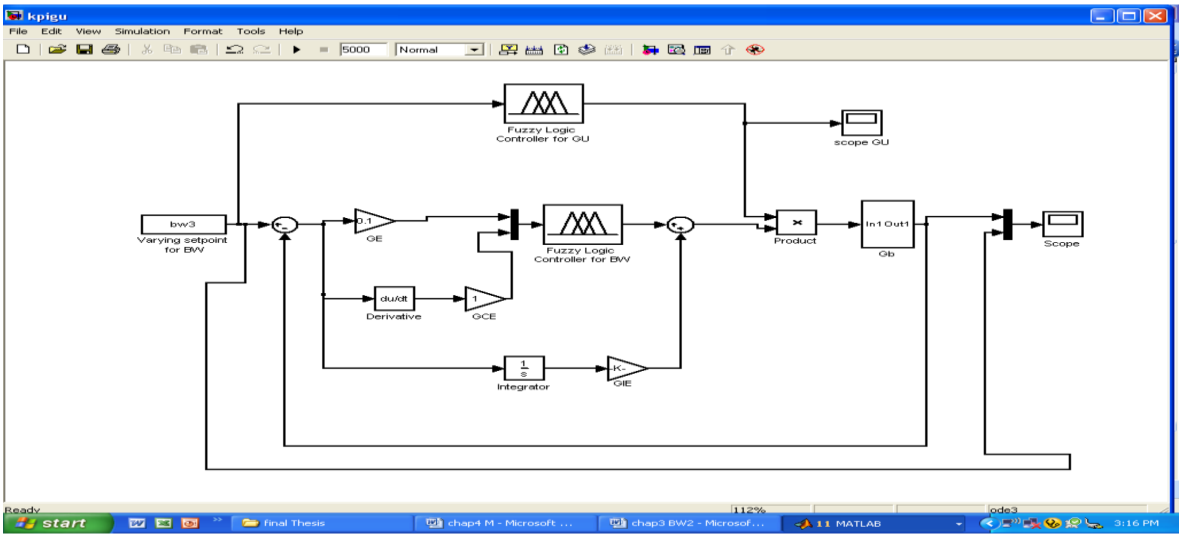

Fig 1.4 Varying input Servo model for basis weight control using FLC

The design parameters for this FLC are now set accordingly i.e. the universe of discourse for the input variables i.e. error in basis weight (e) is now taken according to the maximum error. The universe of discourse of the error is taken as [-20 35]. The universe of discourse for the change in error is taken as [-37 35], while the range of the output variable i.e. the basis weight valve opening (bwvo) is taken as [0 1].

The entire range of inputs as well as the output variables is divided into three subsets each of Gaussian type membership function. The degree of overlapping is taken as 50%. The Fuzzy controller so developed is now implemented for different cases.

The optimum value of GU for each varying input is thus found by the program developed through controller and its values can be seen in the scope window of Fig 1.5.

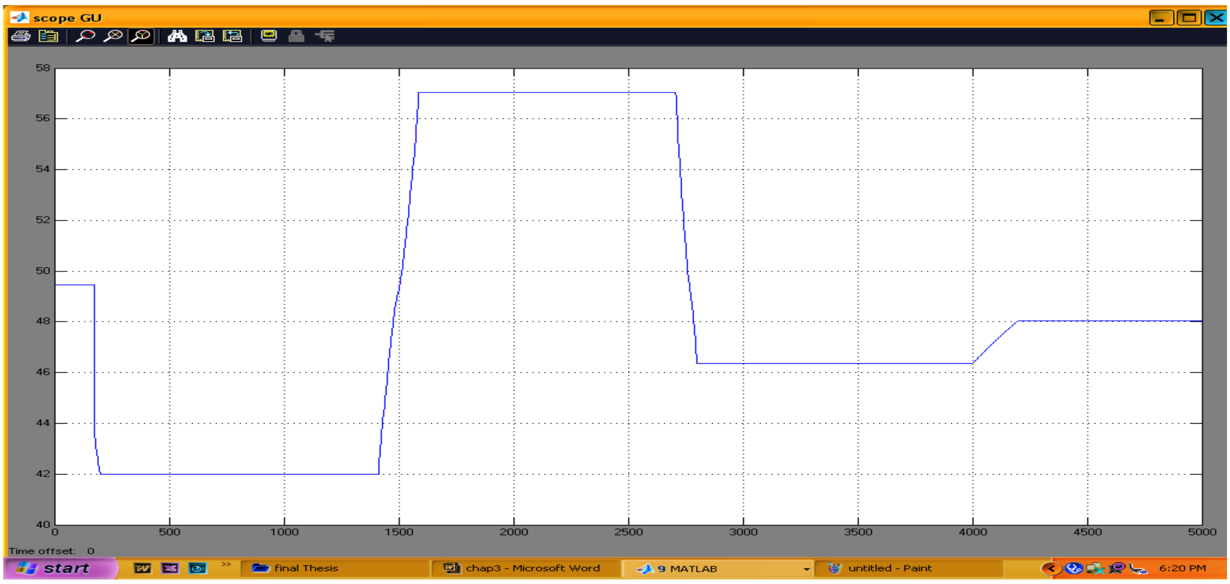

Fig 1.5 Varying values of GU as given by the Fuzzy controller.

Now to find the optimum value of GE for the system, Fuzzy-P model is developed.

III. FUZZY P MODEL

The values of GU are decided according to the program developed, To develop the Fuzzy P model the values of different scaling gains are taken as: GCE = 0, GIE = 0 and different values of GE as: 0.1, 0.15, 0.25 and 0.4, The model of Fig 2.1 is made to run for these values of scaling gains and the results of simulation can be seen in Fig 1.6.

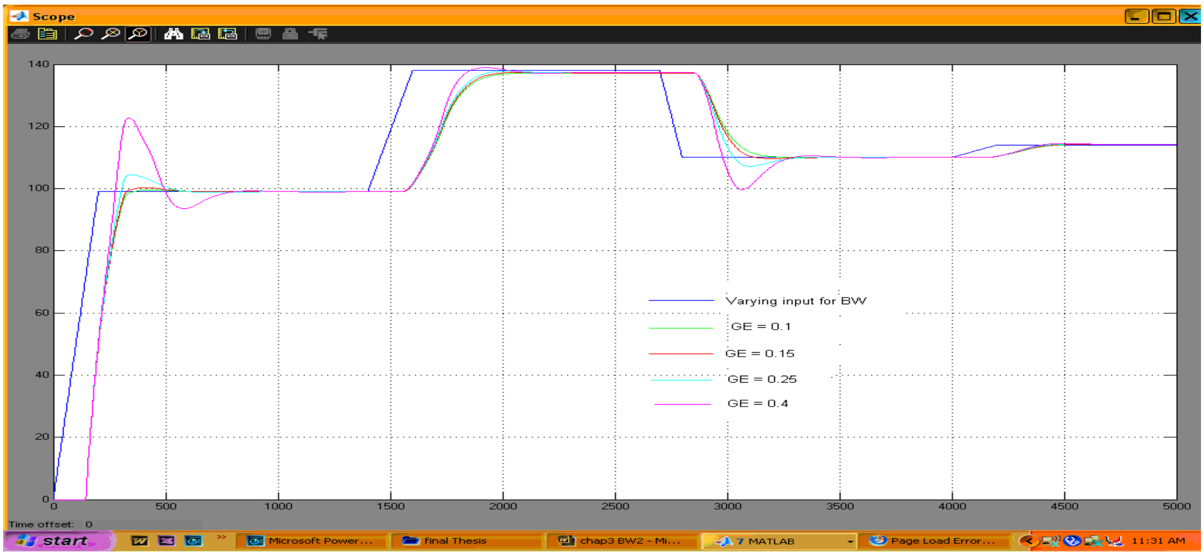

Fig 1.6 Simulation results of BW for varying input servo model for different values of GE = 0.1, 0.15, 0.25 and 0.4.

This shows that as the value of GE increases, the oscillatory behavior increases and the Rise time decreases. For higher values of GE, the output of the system is oscillatory but not unstable. Out of these values, GE=0.1 is taken as the optimum value. Further tests are carried out to find out the value of GCE, hence a Fuzzy-PD model is now developed.

IV. FUZZY PD MODEL

When the value of GCE is added along with the value of GE, the system becomes Fuzzy-PD model. The different values for the scaling factors are now taken as GE= 0.1, GIE= 0 and various values of GCE are taken as: 1, 2, 5 and 10. The simulation results for the same are shown in Fig 1.7.

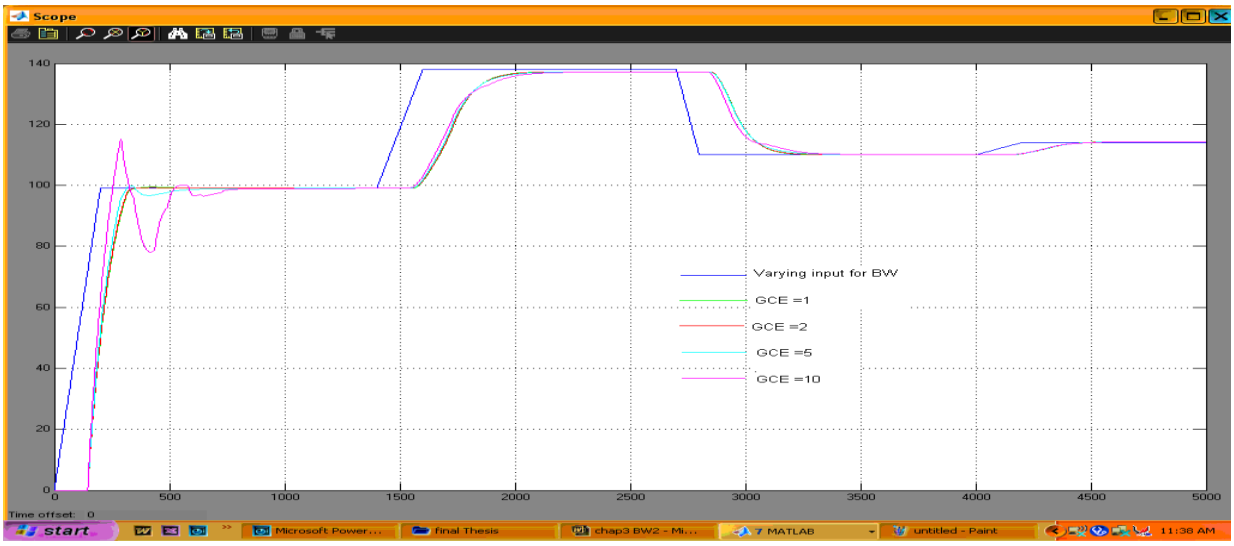

Fig 1.7 Simulation results of BW for varying input servo model for different values of GCE = 1, 2, 5, and 10.

The response for GCE= 1, 5 and 10 is almost coinciding. For GCE=20, the response is a bit oscillatory in the beginning, but becomes stable after some time. It has also been tested that as the value of GCE is increased beyond 20, the response becomes more oscillatory. From the results the value of GCE = 1 is taken as the optimum value as it has comparatively lower Rise time.

V. FUZZY PD+I MODEL

For adding the integral effect to the system, the value of GIE is added. The system is now simulated for GE= 0.1, GCE = 1. Various values of GIE are taken as 0.00001, 0.000001, 0.0000001 and 0.00000001 and the results for the same can be seen in Fig 1.8.

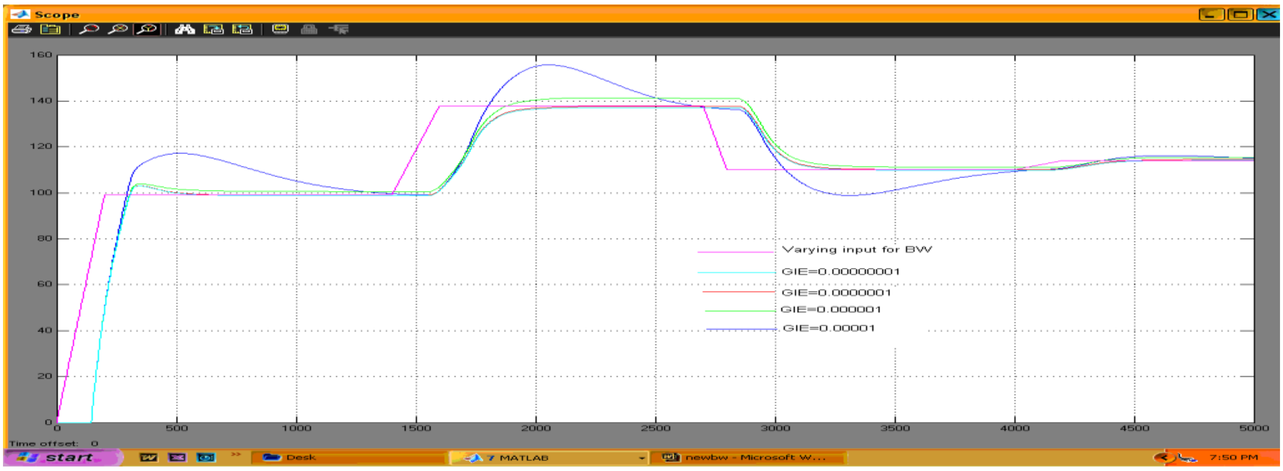

Fig 1.8 Simulation results of BW for varying input servo model for different values of GIE = 0.00001, 0.000001, 0.0000001 and 0.00000001.

It is observed from the results that as the value of GIE increases, the overshoot increase. It also has a little effect on the offset. It has also been tested that if the value of GIE is increased beyond 0.00001, the system becomes unstable. From the above tests, the value of GIE = 0.0000001 is selected as the optimum value for the above system as a higher value of GIE eliminates the steady state error quickly.

VI. RESULTS

The performance of different types of Fuzzy Logic Controllers has been analyzed and it has been seen that GU is responsible for the offset, GE affects the oscillatory behavior, and GCE has a lesser effect on the system response. It affects the rise time of the system, but gives oscillations if the value of GCE is increased to a large extent, while GIE has an effect on the stability of the system.

From all the above tests performed, the tuned values of various scaling gains are taken as: GE=0.1, GCE = 1 and GIE = 0.0000001. Using these values the model was simulated and its output can be seen in the scope window of Fig 1.9.

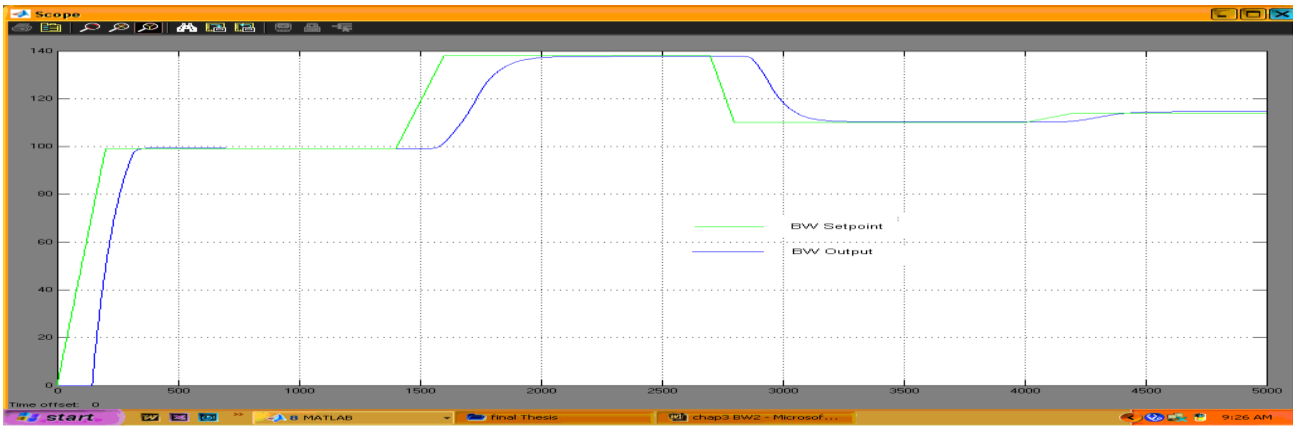

Fig 1.9 The BW output using the Fuzzy Logic Controller

The output of the basis weight (BW Output) moves according to the basis weight set point (BW Set point) but after a delay. The delay measured was 144 seconds. This delay is there in the system because of the process itself. The Fuzzy controller introduces no delay of its own. Now the simulation results for the same process, using the step input and the varying input is performed with a conventional controller. Tuning is done for the constants to get the optimum values for the three constants, and then the results for both types of controllers are compared.

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