Fuzzy logic Controller for Flowing Fluids

Sahil Chandan, Rahul Agnihotri

Abstract— **Flow measurement and control are essential in plant process control. The aim of this paper is to do the comparative study of Fuzzy Logic controller and conventional PID controller for flowing fluids.These two controllers are implemented using MATLAB software.The fuzzylogic toolbox of the Matlab is to be used in order to implement the proposed controller. During the past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the applications of fuzzy set theory, especially in the realm of industrial processes, which do not lend themselves to control by conventional methods because of a lack of quantitative data regarding the input-output relations.**

Index Terms— **Conventional control, Flow control, Fuzzy logic control, Matlab.**

I. Introduction

Control of liquid flow system is a routine requirement in many industrial processes. The control action of chemical and petroleum industries include maintaining the controlled variables. Fuzzy logic control (FLC) can be applied for control of liquid flow and level in such processes [1]. This technique is particularly attractive when the process is nonlinear.

With most liquid flow measurement instruments, the flow rate is determined inferentially by measuring the liquid's velocity or the change in kinetic energy. Velocity depends on the pressure differential that is forcing the liquid through a pipe or conduit. Because the pipe's cross-sectional area is known and remains constant, the average velocity is an indication of the flow rate. The basic relationship for determining the liquid's flow rate in such cases is:

$$Q = V \times A \qquad (1)$$

where,

Q = liquid flow through the pipe
V = average velocity of the flow
A = cross-sectional area of the pipe

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Other factors that affect liquid flow rate include the liquid's viscosity and density, and the friction of the liquid in contact with the pipe. Direct measurements of liquid flows can be made with positive-displacement flow meters. These units divide the liquid into specific increments and move it on. The total flow is an accumulation of the measured increments, which can be counted by mechanical or electronic techniques. The performance of flow meters is also influenced by a dimensionless unit called the Reynolds Number. It is defined as the ratio of the liquid's inertial forces to its drag forces.

$$R = \frac{3160 \times Q \times Gt}{D \times \eta} \qquad (2)$$

Where, R = Reynolds number
Q = liquid's flow rate, gpm
Gt = liquid's specific gravity
D = inside pipe diameter
η = liquid's viscosity.

Laminar and turbulent flow are two types normally encountered in liquid flow measurement operations. Most applications involve turbulent flow, with R values above 3000. Viscous liquids usually exhibit laminar flow, with R values below 2000. The transition zone between the two levels may be either laminar or turbulent.

II. Main Idea FLC

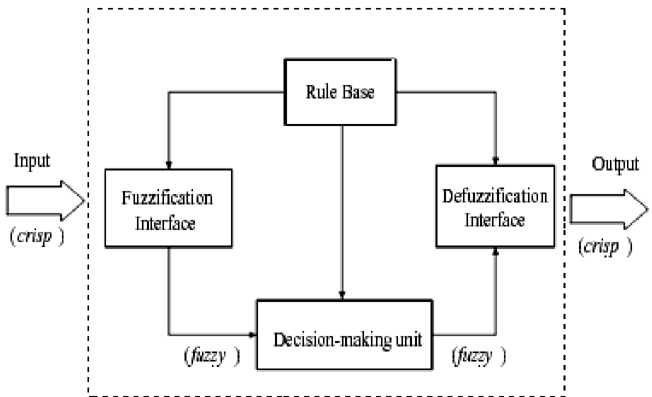

Figure 1: Basic Configuration of a fuzzy logic system.

Fuzzy logic control is derived from fuzzy set theory. In fuzzy set theory, the transition between membership and non-membership can be graded. Therefore, boundaries of fuzzy sets can be vague and ambiguous, making it useful for approximate systems. Fuzzy Logic Controller (FLC) is an

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attractive choice when precise mathematical formulations are not possible [3]. Other advantages are:

- It can work with less precise inputs.
- It doesn't need fast processors.
- It needs less data storage in the form of membership functions and rules than conventional look up table for nonlinear controllers.
- It is more robust than other non-linear controllers.

There are three principal elements to a fuzzy logic controller.
A Fuzzification module (Fuzzifier)
B Rule base and Inference engine
C Defuzzification module (Defuzzifier)

III. PRINCIPLES OF FUZZY MODELLING

The general algorithm for a fuzzy system designer can be synthesized as follows.

A Fuzzification

1) Normalize of the universes of discourses for the fuzzy input and output vectors.
2) Choose heuristically the number and shape of the membership functions for the fuzzy input and output vectors.
3) Calculate of the membership grades for every crisp value of the fuzzy inputs.

B Fuzzy inference

4) Complete the rule base by heuristics from the view point of practical system operation.
5) Identify the valid (active) rules stored in the rule base.
6) Calculate the membership grades contributed by each rule and the final membership grade of the inference, according to the chosen Fuzzification method.

C Defuzzification

7) Calculate the fuzzy output vector, using an adequate Defuzzification method.
8) Simulation tests until desired parameters are obtained.
9) Hardware implementation.
From the beginning, a fuzzy-style inference must be accepted and the most popular are:

MAMDANI- style inference, based on Lotfi Zadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes that expects all output membership functions to be fuzzy sets. It is intuitive, has widespread acceptance, is better suited to human input, but its main limitation is that the computation for the defuzzification process lasts longer.

SUGENO- style inference, based on Takagi-Sugeno-Kang method of fuzzy inference, in their common effort to formalize a systematic approach in generating fuzzy rules from an input-output data set, that expects all membership functions to be a singleton. It has computational efficiency, works well with linear techniques (e.g. PID control, etc.) works well with optimization and an adaptive techniques guaranties continuity of the output surface, and is better suited to mathematical analysis. The results are very much similar to Mamdani style inference.

IV. PROBLEM FORMULATION

Measuring and controlling flow rate in process plants presents challenges of its own. Both gas and liquid flow can be measured in volumetric or mass flow rates, such as liters per second or kilograms per second. These measurements can be converted between one another if the fluid density is known. The density for a liquid is almost independent of the liquid conditions; however, this is not the case for gas, the density of which depends greatly upon pressure, temperature and to a lesser extent, the gas composition [2].

With so many different variables that could affect flow rate, flow measurement and control is susceptible to disturbances. Because of this, flow controllers need to be robust in order to optimize the performance of a plant. Fuzzy Logic Controller is proposed to replace the conventional PID controller due to its superior applicability and robustness. PID controller works well only if the mathematical model of the system could be computed [4]. Hence it is difficult to implement PID control for variable as well as complicated systems. But Fuzzy logic control doesn't require any precise mathematical model and works good for complex applications also. Fuzzy logic control is able to handle imprecision and uncertainty [7].

V. SOFTWARE USED

Matlab

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran.

VI. PROJECT METHODOLOGY

A. Procedure Identification

This project can be divided into two major sections; simulation and implementation. The following flowchart show in figure2 exemplifies the procedure of which this project will be carried out.

B. Time Dependent Performance analysis

The time dependent characteristics are those that depends upon the time. These characteristics varies with time and analysed with the help of the time response graph. With these parameters the proposed controller can be analysed that how the fuzzylogic controllercan be better than the conventionally used PID controller.

There are various time dependent characteristics that are used for the analysis of the system like settling time, rise time, delay time, steady state error, peak overshoot etc.

VII. RESULTS

The figure 3 & 4 shows the response of the conventional PID controller and the response of the fuzzylogic controller to the step input. Then the figure 5 shows the input and output response simultaneously of the fuzzylogic controller. Yellow line shows the input and pink line shows the output. Figure 6& 7 shows the performance response of PID and Fuzzylogic controller respectively.

VIII. CONCLUSION

In this paper the performance of the conventional PID controller and the Fuzzylogic controller is compared. The response of the PID controller is oscillatory which can damage the system. But the response of the fuzzylogic controller is free from these dangerous oscillations in the transient period. Hence the proposed Fuzzylogic controller is better than than the conventionally used PID controller.

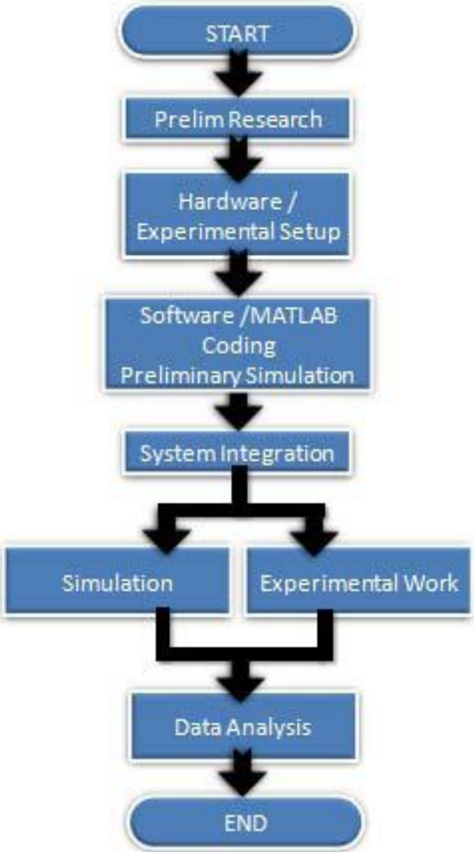

Fig2: Flowchart of Project implementation

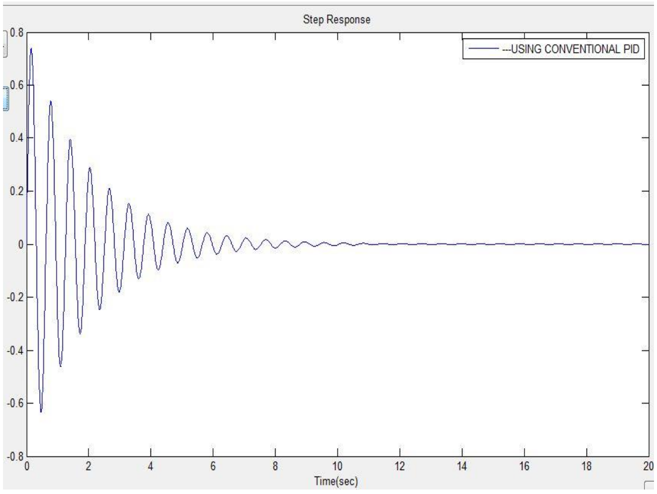

Fig3. The step response of the conventional PID controller.

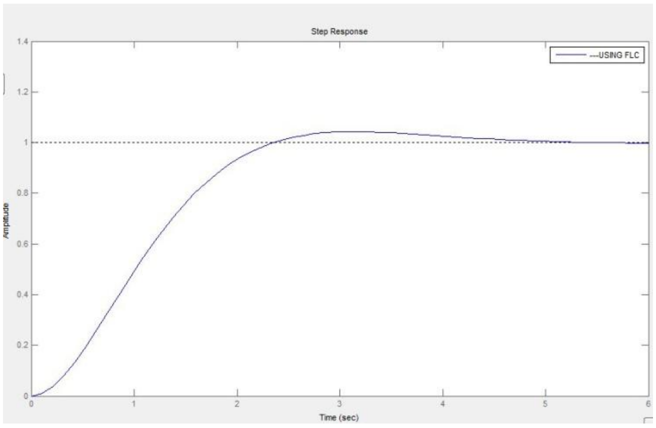

Fig.4 shows the step response of the fuzzylogic controller.

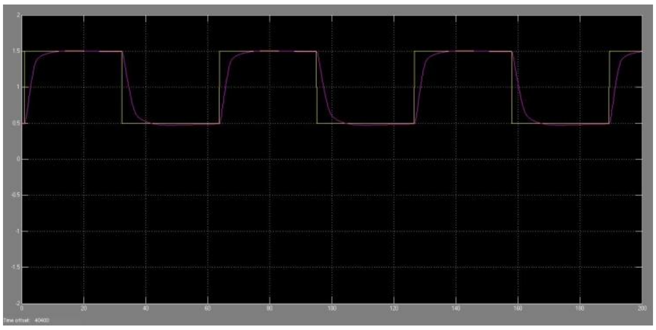

Fig.5 The yellow line shows input and pink line shows output and it can be seen that output is very close to input.

Fig.6 shows the performance of conventional PID controller

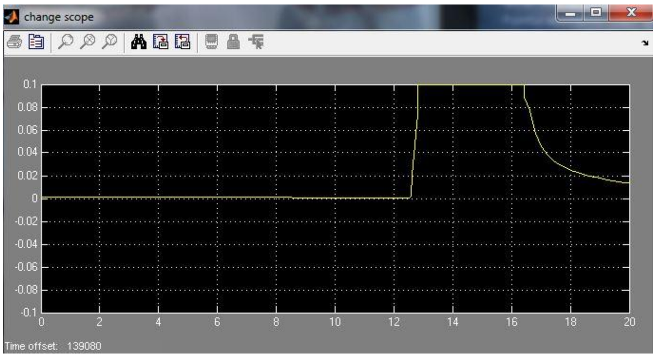

Fig.7 shows the performance of the fuzzylogic controller

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