# TUNING OF PID CONTROLLERS USING FUZZY

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## Abstract

*In this paper a new method for autotuning SISO and MIMO PID fuzzy logic controllers (FLC) is proposed. The fuzzy autotune procedure adjusts on-line the parameters of a conventional PID controller located in the forward loop of the process. Fuzzy rules are based on the representation of human expertise on how can be the behavior of gain and phase margins of a control system to efficiently compensating the system errors. Performance and robust stability aspects are assessed by practical and simulated examples. There are many methods proposed for the tuning of PID controllers out of which Ziegler Nichols method is the most effective conventional method. In this paper, optimum response of the system is obtained by using fuzzy logic controllers. The method used here is fuzzy set point weighting. A comparison of the performance of fuzzy set point weighted controller is performed not only with the conventional methods of tuning but also with different shapes and numbers of designed membership functions.*

***Keywords:*** *PID (proportional-integral-derivative), Fuzzy Logic controller (FLC), Ziegler Nichols Method (ZN), Fuzzy Set Point Weighting Controller (FSPWC), Membership Functions (MF).*

## 1. Introduction

For years the fuzzy logic control has proved its broad potential in industrial applications (Altrock and Gebhardt, 1996; Qin, *et al*., 1998). The fuzzy control theory has been applied to a number of systems with single-input and single-output (SISO) structures, mainly to overcome uncertain parameters and unknown models (Hu *et al*, 1999). Generally, fuzzy control shows good performance for controlling nonlinear and uncertain systems that could not be controlled satisfactorily by using conventional controller, for example, a conventional PID controller (Ying, *et al*., 1990). Also, in applications when there are multiple-input and multiple-output (MIMO) systems with strong loop interactions, conventional controllers do not work well and advanced control conceptions are required. Control literature of MIMO fuzzy logic controllers (MIMO FLC) shows limited results and a great effort has been used by researchers to derive stable control strategies. Usually, a MIMO FLC is tuned by trial-and-error that means a tedious and time-consuming task, and design techniques for systematic tuning must be obtained. Also, MIMO FLC applications are frequently solved by using the conventional decoupling theory and with single FLCs, resulting in high-dimensional rule-bases that may not be implemented in practical systems.

Tuning of PID controllers has always been an area of active interest in the process control industry. Ziegler Nichols Method (ZN) is one of the best conventional methods of tuning available now. Though ZN tunes systems very optimally, a better performance is needed for very fine response and this is obtained by using Fuzzy Logic (FL) methodology which is highly effective. The FL methodology used in this paper is applied in the form of Fuzzy Set Point Weighting Controller (FSPWC). The idea of multiplying the set-point value for the proportional action by a constant parameter less than one is effective in reducing the overshoot but has the drawback of increasing the rise time. To achieve both the aims of reducing the overshoot and decreasing the rise time, a fuzzy module can be used to modify the weight depending on the current output error and its time derivative.

**TUNING OF FUZZY PID CONTROLLER: SISO CASE - FPID-SISO**

Since the proposed controller uses a nonlinear fuzzification algorithm and output membership functions, the controller can be considered as a nonlinear PID where parameters are tuned on-line based on error *e(t)* and change of error *de(t)* about a setpoint *r(t)*, as shown in Fig. 1. The system error is compensated by a set of fuzzy linguistic rules which are derived from the experience and knowledge of a control designer on how can be the behaviour of gain and phase margins for efficiently compensating the system error. In this sense the FPID-SISO can be interpreted as a fuzzy gain scheduling PID controller

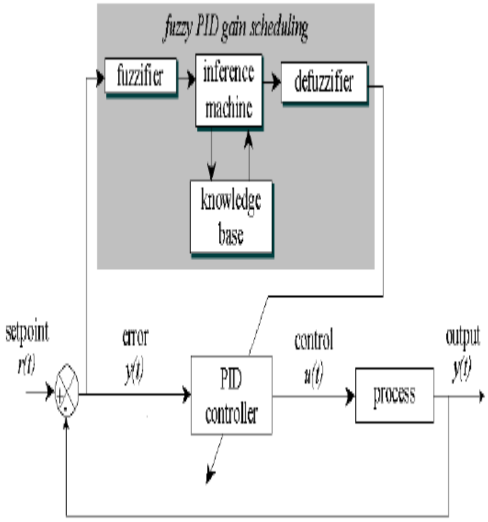



**Fig1: Fuzzy logic controller system**

**Principle of FLC**

**The FLC implementations incorporate the following stages:**

(1) Fuzzification: Fuzzification implies the process of transforming the crisp values of the inputs of a controller to the fuzzy domain.

(2) Knowledge Base: The knowledge base of FLC consists of database and the rule base.

a. Data base: It is used to provide necessary information for functioning of fuzzification module, rule base and defuzzification module.

b. Rule base: The function of rule base is to represent in a structured way the control policy of an experienced control engineer. This is generally taken the expert in the field otherwise, the knowledge is acquired by having practical experience.

(3) Fuzzy inference engine (system): A fuzzy inference engine has a simple input-output relationship. Input data from the external world is processed

by the fuzzy inference engine to produce the data to be used back in the external world. The events taking place in this process are referred as the basic fuzzy inference algorithm. Mamdani and TakagiSugeno fuzzy systems are the examples of fuzzy inference systems.

(4) Defuzzification: is a process of transforming the fuzzy sets assigned to a control output variable into a crisp value. There is various method of defuzzification.

- Centre of Area Method (COA)
- Mean of Maximum Method (MOM)
- Bisector Method Largest of Maximum (LOM)
- Smallest of Maximum (SOM)

**Advantages of Using Fuzzy Logic Controller**

- Computing with words also allow us to develop mathematical models of events articulated in language only.
- By fuzzifying crisp data obtained from measurements, fuzzy logic enhances the robustness of a system without fuzzification systems designed to act at certain input data points would not know what to do when data is somewhat corrupted.
- Representing a solution with fuzzy sets reduces computational burden. In some cases fuzzy technology makes a solution possible that would be otherwise unthinkable due to cost of computing every single crisp data point.

## 2.0 LITERATURE REVIEW

**Hyeong-Pyo Hong (2002)** The authors describe an autotuning method for an intelligent PID (proportional-integral-derivative) control system. This method is based on the settling time of the process and is applied to the autotuning PID controller by using fuzzy logic. The autotuning algorithm proposed can tune the PID parameters online using the response characteristics of the PID control system. The performance of the controller was verified by computer simulation. Simulation shows good results. The proposed controller was tuned automatically to the optimal PID parameters under various initial conditions.

**Gaddam Mallesham (2006)** In this paper the new methodology for designing of PID controller is presented. PID controllers are the most widely used controllers in the industry. Although much architecture exists for control systems, the PID controller is mature and well-understood by practitioners. For these reasons, it is often the first choice for new controller design. There are many methods proposed for the tuning of PID controllers out of which Ziegler Nichols method is the most effective conventional method. In this paper, optimum response of the system is obtained by using fuzzy logic controllers. The method used here is fuzzy set point weighting. A comparison of the performance of fuzzy set point weighted controller is performed not only with the conventional methods of tuning but also with different shapes and numbers of designed membership functions.

**Afshan Ilyas (2013)** This paper presents a method for tuning of conventional PID controller. Simplicity, robustness, wide range of applicability and near-optimal performance are some of the reasons that have made PID control so popular in the academic and industry sectors. Recently, it has been noticed that PID controllers are often poorly tuned and some efforts have been made to systematically resolve this matter. Thus Fuzzy logic can be used in context to vary the parameters values during the transient response, in order to improve the step response performances. Simulation analysis has been carried out for the different processes by conventional and different defuzzification techniques and the results indicate that the values of percentage overshoot are reduced by using fuzzy logic mechanism.

## 3. AUTOTUNING OF FUZZY PID CONTROLLER: MIMO CASE - FPID-MIMO

With additional conditions, the proposed FPID-SISO controller, can be generalized for the MIMO case. As in the SISO case, the FPID-MIMO can be divided into two stages: identification and controller design phases. The identification phase copes with the auto-tuning capacity of the controller and to do so, a scheme of sequential multivariable identification is implemented. In the controller design phase, the main ideas applied to the FPID-SISO case is extended to the MIMO case. The reduced dimension of the rule base as well its simplicity corresponds to the most important features of the proposed fuzzy scheme. In order to asses the FPIDMIMO performance the Wood-Berry distillation column (Luyben, 1990) is evaluated. Simulations have shown that the controller is capable of providing good overall system performance.

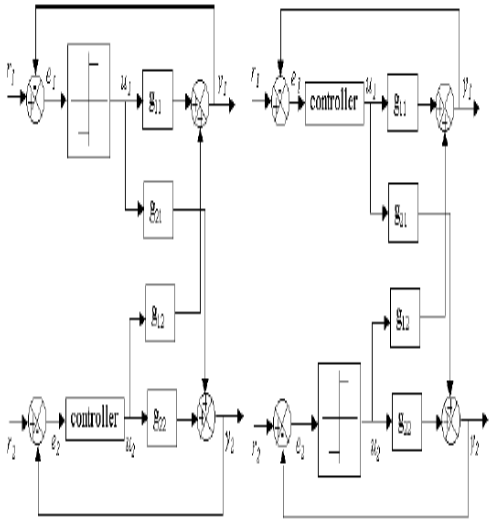



**Fig 2. Identification under sequential relay**

### 3.2 Autotuning multivariable fuzzy logic controller engine

The multivariable fuzzy logic controller proposed in this paper utilizes fuzzy rules to determine the set of PID parameters. As in the SISO case, control signals in the MIMO case are generated by PID controllers

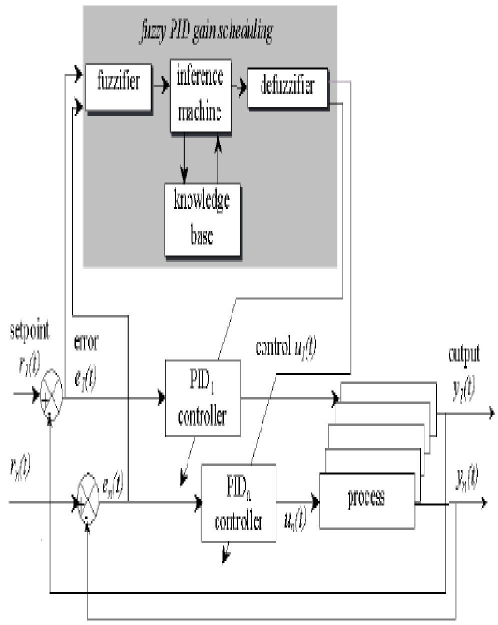
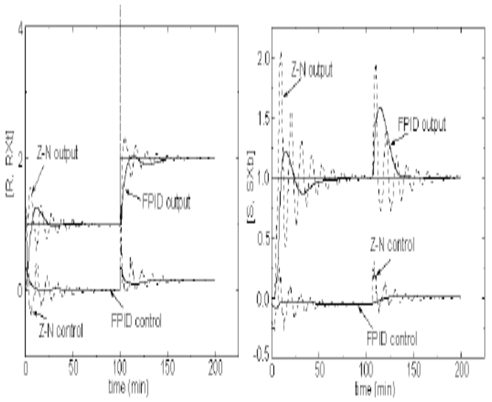


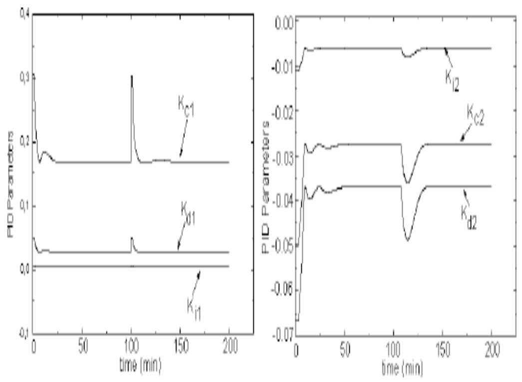
**Fig 3. Fuzzy gain scheduling PID controller: MIMO case**

## 4. Results




(a) (b)

Control, output and setpoint for WB column
(a) pair R-Xt (b) pair S-Xb.




(a) (b)

FPID-MIMO parameters.

## 4. Conclusion

The main goal of this paper is to provide to the plant operators with easy-to-understand fuzzy PID method for quickly achieving satisfactory control over unknown monovariable and multivariable systems. Despite its simplicity, the proposed method yielded monovariable and multivariable designs and a superior behavior to that resulting from empirical method based on trial-and-error procedure. The method has shown be adequate for practical

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