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Simulation Study of IMC and Fuzzy Controller for HVAC System

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Abstract: This paper presents how the fuzzy logic controller is used to solve the control problems of complex and non linear process and show that it is more robust and their performance are less sensitive to parametric variations than conventional controllers. These systems will yield a linear response when compared to ordinary controllers. The main advantage of Fuzzy control over conventional controllers is regulation can be done without over shoot. *Copyright © 2009 IFSA.*

Keywords: Simulation, Internal Model control, Fuzzy control, HVAC system

1. Introduction

In conventional control systems, the design of controllers is based on a precise description of the process, through state equations and transfer functions, etc. When processes are complex, or their controls require high degree of performance quality, finding a control algorithm may be an intractable mathematical problem, due to non-existence of reliable models that explain the process dynamic suitably.

Moreover, there are many processes in which the operator is necessary, even in the low level control loop. Most of the chemical process in real time are non linear, so the response of the controller will not yield a useful result. Such responses will always arise while using conventional controllers. In order to eliminate such controversial responses, fuzzy algorithm is introduced to get a desired response.

The method of expressing an operator's judgment based on his/her empirical knowledge by fuzzy reasoning. The controller is composed of a set of linguistic control rules which are conditional linguistic statements expressing this knowledge, and an associated inference mechanism. The rules use

Fuzzy Logic whose principles were first enunciated by many authors [1-5]. This paper reports the simulation study of Fuzzy and Internal Model controller for HVAC system.

2. System Description

HVAC stands for heating, ventilation and air conditioning. Air is taken through an outdoor air intake that is usually a louvered opening on the top or side of the building. Atmospheric pressure pushes the air through a damper, which regulates the amount of outdoor air (OA) taken in by the system. At this point, already conditioned return air (RA) from the system can be mixed with the outdoor air to form "mixed air."

The mixed air goes through pre-filter where larger dust particles, insects, leaves, etc. are caught. A more efficient filter is usually present to address small particles. After the filters, the air enters a centrifugal fan. Through a fan outlet, the air is under positive pressure and being pushed towards coils where the air is either heated or cooled, depending on the temperature of the air and the season. Under the coils lies a drain pan to collect any water condensing on the coils.

If a humidifier or dehumidifier is needed it is usually incorporated into the cycle at this point. The air travels through ductwork where it reaches a distribution box and may travel through smaller ducts to supply the terminals, registers or diffusers into the workspace. Once the air reaches its destination, it is returned through an air register (usually through a louvered door that opens into a space above the ceiling tiles) in the form of return air that will become mixed air or exit the building.

3. Process Identification

In the HVAC system the supply air pressure is regulated by the speed of a supply air pressure and vice versa. The dynamics from the control signal feeding to the fan variable speed drive to the supply air pressure can be modeled as a second order plus dead time plant. This is achieved through the use of a fuzzy logic controller that takes into account a range of human comfort criteria in the formulation of the control action that should be applied to the heating system to bring the space to comfort conditions.

The resulting controller is free of the set up and tuning problems that hinder conventional HVAC controllers. Simulation results show that the proposed control strategy when compared with conventional control is better.

In order to demonstrate the effectiveness and robustness of the Fuzzy controller a second order air pressure control loop of a HVAC system has been taken as an example[6].

$$G(s) = \frac{0.81e^{-2s}}{(0.97s+1)(0.1s+1)}$$

4. Simulation

4.1. Internal Model Control (IMC)

The controller design involves the following three steps:
1).The process transfer function G(s) is factorized into invertible and noninvertible elements to obtain a stable controller.

2). A filter is added to make the controller proper. Since it is desirable to track the set point changes
3). Then the IMC controller is designed with the obtained data. The designed IMC is represented in the Fig. 1.

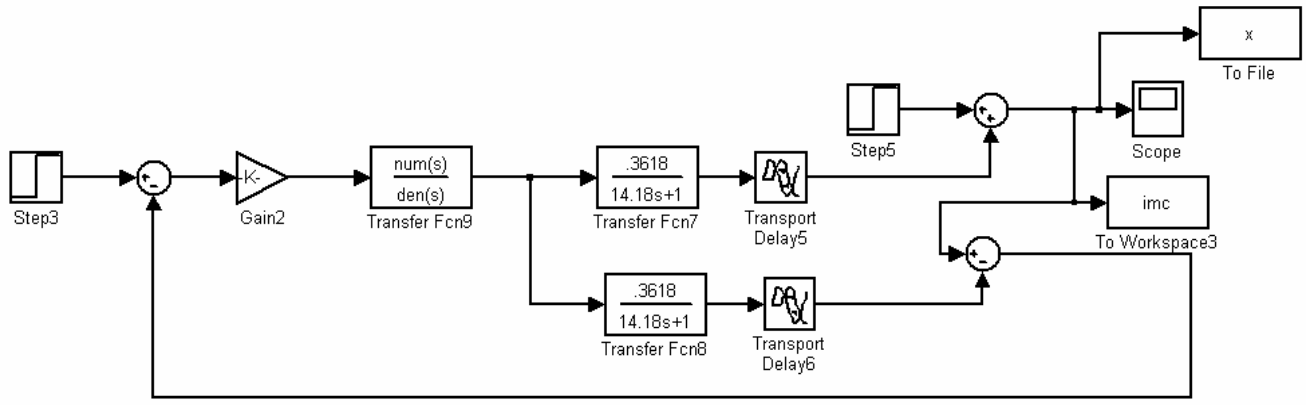


Fig. 1. Design of IMC controller.

4.2. Fuzzy Controller

Most commercial fuzzy products are rule-based systems that receive current information in the feedback loop from the device as it operates and control the operation of a mechanical or other device. Crisp input information from the device is converted into fuzzy values for each input fuzzy set with the fuzzification block. The universe of discourse of the input variables determines the required scaling for correct per-unit operation. The scaling is very important because the fuzzy system can be retrofitted with other devices or ranges of operation by just changing the scaling of the input and output.

The decision-making-logic, Fuzzy Inference, determines how the fuzzy logic operations are performed (Sup-Min inference), and together with the knowledge base determine the outputs of each fuzzy IF-THEN rules. Those are combined and converted to crispy values with the defuzzification block. The output crisp value can be calculated by the center of gravity or the weighted average. The input and output membership function is shown below.

In order to process the input to get the output reasoning six steps are involved in the creation of a rule based fuzzy system:
1. Identify the inputs and their ranges and name them.
2. Identify the outputs and their ranges and name them.
3. Create the degree of fuzzy membership function for each input and output.
4. Construct the rule base that the system will operate under.
5. Decide how the action will be executed by assigning strengths to the rules.
6. Combine the rules and defuzzify the output.

The selection of the control rules for the system, error E and change in the error, CE are done. Rules are developed using the inputs E and CE to give an output and are shown in Table 1.

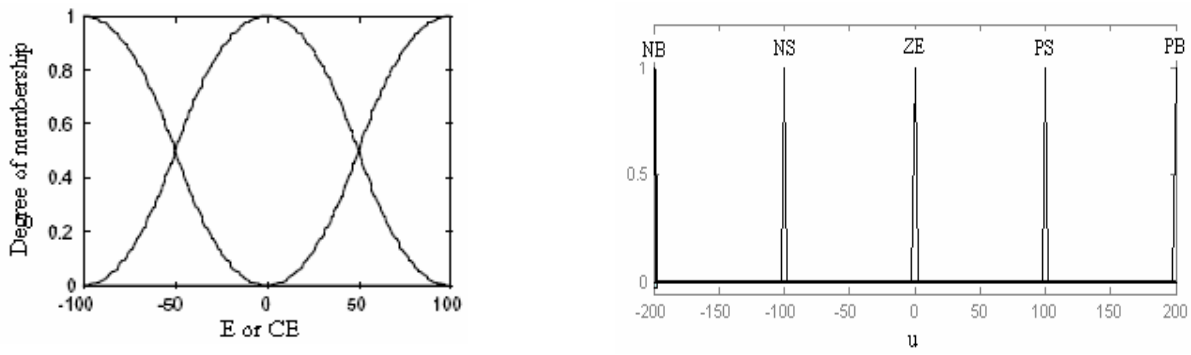
The FLC membership functions are defined over the range of input and output variable value and linguistically describe the variable's universe of discourse. Each variable is decomposed into a set of fuzzy regions which are called labels. Each label indicates a linguistic term such as ZE for zero, N for negative, P for Positive, B for Big and S for small.

Table 1. Fuzzy control rules – HVAC system.

		Change of error (CE)		
		NB	ZE	PB
error (E)	NB	NB	NS	ZE
	ZE	NS	ZE	PS
	PB	ZE	PS	PB

The universe of discourse for triangular curve membership function (MF) for both the inputs, E and CE, are chosen for a particular range with overlap between MF about 50.

The output universe for the controllers is chosen as shown in Fig. 2. It shows that the inputs, E and CE, have linguistic terms: NB, ZE and PB while the output fuzzy terms shown in Fig. 2 have five terms namely NB, NS, ZE, PS and PB. The simulation block diagram of fuzzy controller is shown in Fig.3.



(a) (b)

Fig. 2. The input and output membership function.

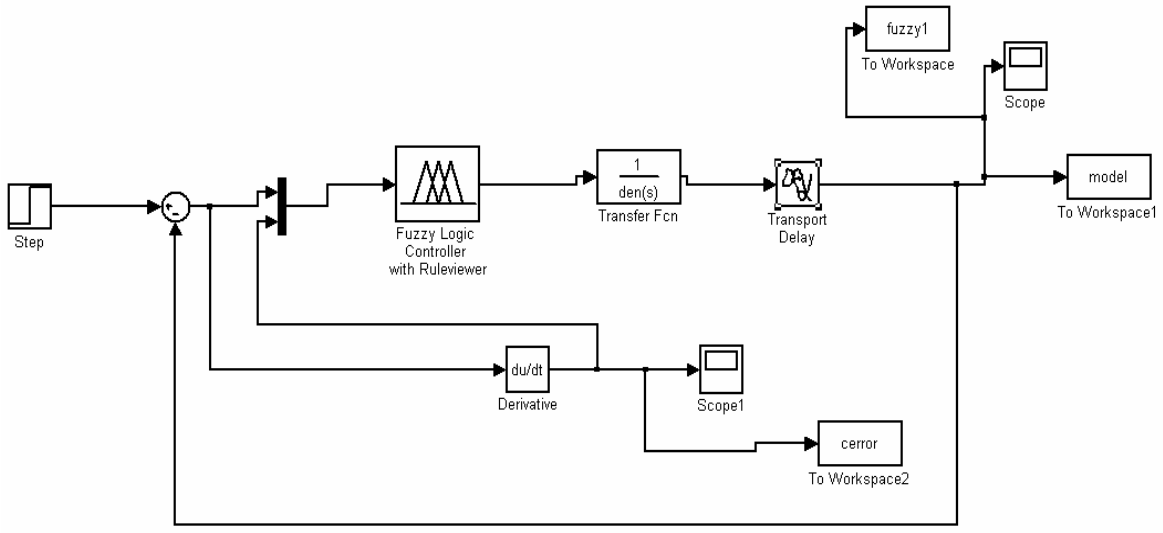


Fig. 3. Simulation Block diagram of fuzzy controller.

5. Result and Discussion

Fig. 4 shows response of IMC controller whereas Fig. 5 presents the response of Fuzzy controller. Fig. 6 presents comparative performance of both IMC and fuzzy controller.

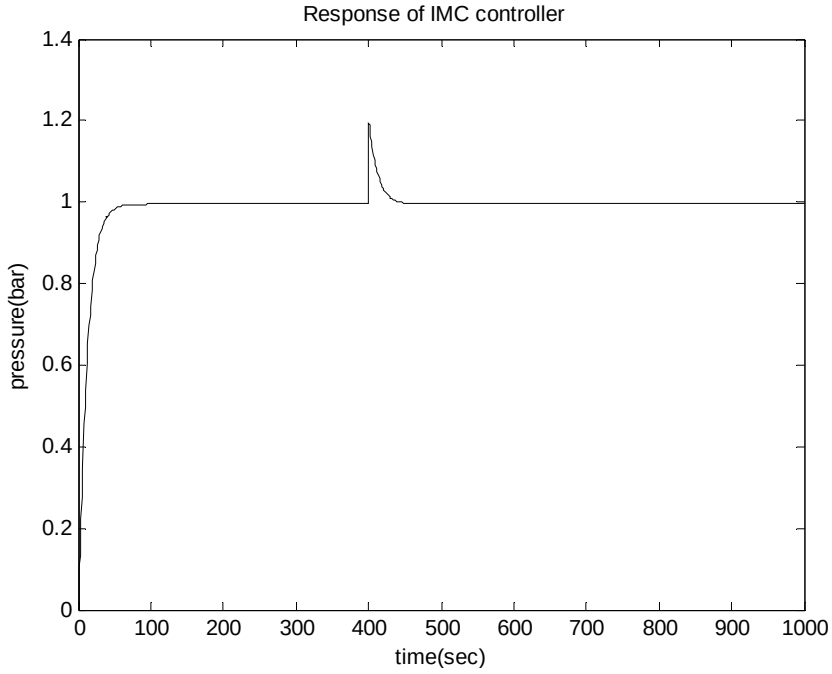


Fig. 4. Response of IMC Controller.

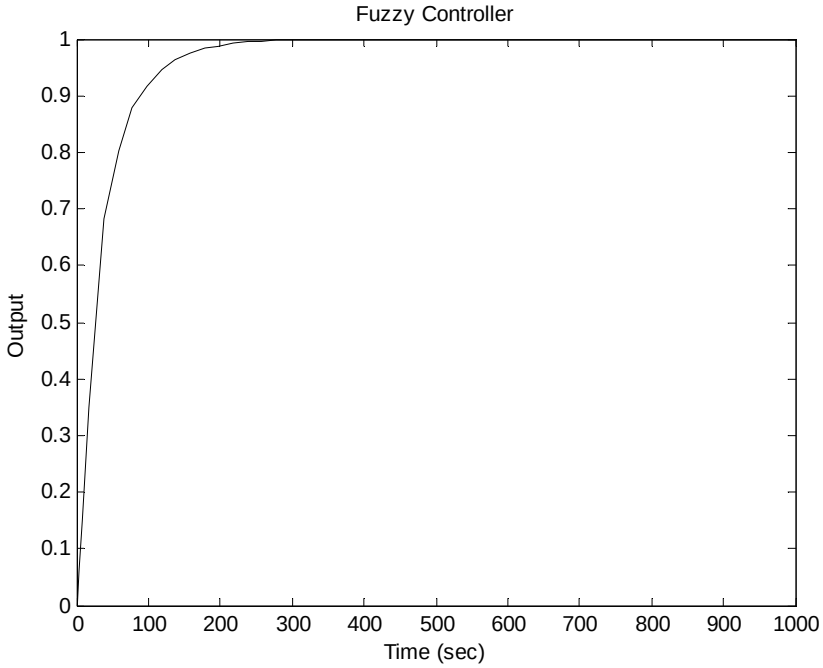


Fig. 5. Response of Fuzzy Controller.

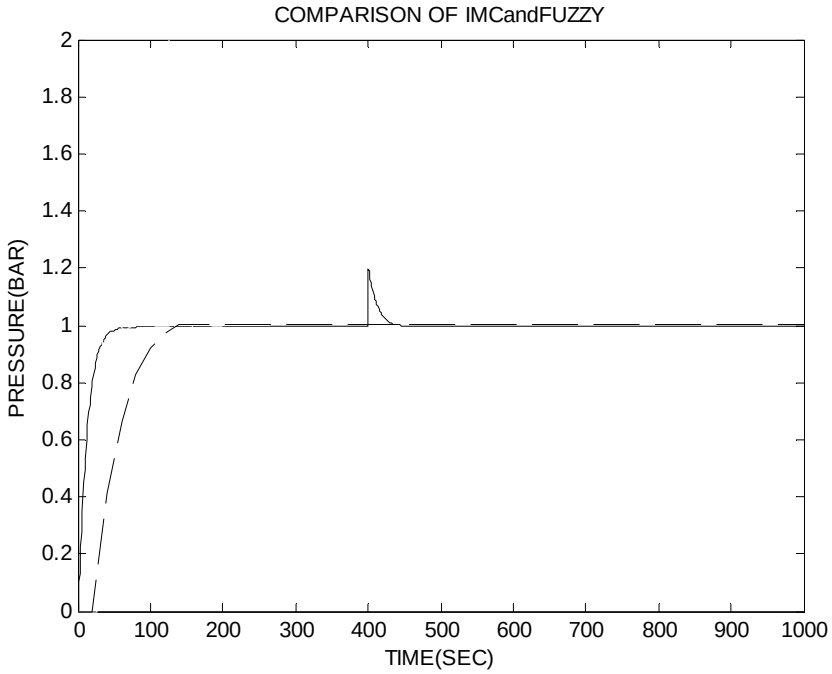


Fig. 6. Comparison of IMC and Fuzzy Controller.

Table 2. Performance analysis different controller for HVAC system.

Name of the Controller	Rise time	Settling time	Overshoot	ISE	IAE	ITAE
Internal Model controller	36	450	.0558	3.2678	1.0398	0.0808
Fuzzy controller	22	400	.0323	1.0897	0.0186	.0.004245

The comparative performance of both IMC and fuzzy controller are given in Table 2.The results given in Table 2 emphasize that the fuzzy controller shows a minimum dynamic response time than IMC controllers.

This response is attributed to the nonlinearities of fuzzy systems. It is observed that fuzzy controllers eliminate steady-state error and they do not exhibit overshoot.

During the transients, at the beginning of a step change or after a disturbance, the fuzzy controllers are quicker to converge to the set point than the IMC controller. It is also noted that the set point and the disturbance responses of the fuzzy are much better and faster than IMC controller.

6. Conclusion

The design and control of a fuzzy controller for pressure regulation has been studied. The response of the fuzzy controller is compared with the output of internal model controller. The responses clearly indicated an improved result over conventional control. The main advantage of Fuzzy control over conventional controllers is regulation can be done without over shoot as observed from the response.

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Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

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- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
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