Self-Tuning Fuzzy PI Controller and its Application to HVAC Systems

A. K. Pal and R. K. Mudi

***Abstract*— In this paper, a Self-tuning Fuzzy PI controller is used for the supply air pressure control loop for Heating, Ventilation and Air-Conditioning (HVAC) system. The self-tuning Fuzzy PI controller (STFPIC) is adjusted the output scaling factor on-line by fuzzy rules according to the current trend of the controlled process. The rule-base for tuning the output-scaling factor is defined on error and change of error of the controlled variable. Ziegler-Nichols tuned PI or PID controller performs well around normal working conditions, but its tolerance to process parameter variations are severely affected. The STFPIC is used here to overcome these shortcomings. Comparing with PID and Adaptive Neuro-Fuzzy (ANF) Controllers, simulations results show that STFPIC performances are better under normal conditions as well as when the HVAC system encounters large parameter variations.** *Copyright © 2008 Yang's Scientific Research Institute, LLC. All rights reserved.*

***Index Terms*— PID control, HVAC system, self-tuning fuzzy PI controller, adaptive neuro-fuzzy method..**

I. INTRODUCTION

HEATING, Ventilation and Air-Conditioning (HVAC) systems require control of environmental variables such as pressure, temperature, humidity etc. Like in other industrial applications, most of the controllers commissioned in HVAC systems are of Proportional-Integral-Derivative (PID) type. The conventional PID controllers are widely used in industry due to their simplicity in arithmetic, ease of using, good robustness, high reliability, stabilization and zero steady state error. But HVAC system is a non-linear and time variant system. It is difficult to achieve desired tracking control performance since tuning and self-adapting adjusting parameters on line are a scabrous problem of PID controller. Over the past few decades, several methods for determining PID controller parameters have been developed. Some employ information about open-loop step response, for example Cohen-Coon reaction curve method [1]; other methods are knowledge of the Nyquist curve, e.g., the Ziegler-Nichols frequency-response method. However, these methods use only a small amount of information about the dynamic behavior of the system, and often do not provide good tuning.

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A. K. Pal, Applied Electronics and Instrumentation Engineering Department, Heritage Institute of Technology, Chowbaga Road, Anandapur, Kolkata-700107. R. K. Mudi, Instrumentation and Electronics Engineering Department, Jadavpur University, Kolkata. Email: arabindak_pal@yahoo.com(A. K. Pal)

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It has been reported that fuzzy logic controller is very suitable for non-linear system and even with unknown structure [2, 3]. In [4 - 15], various fuzzy PI / PID hybrid control schemes are discussed to improve PI / PID control performance. The tuning procedure can be a time-consuming, expensive and difficult task [16, 17]. This problem can be easily eliminated by using self-tuning scheme for fuzzy PI / PID controller.

Generally a skilled human operator always tries to manipulate the process input, usually by adjusting the controller gain based on the current process states (error and change of error) to get
the process "optimally" controlled. We used a simple but robust self-tuning scheme, where the controller gain is adjusted continuously with the help of fuzzy rules. Here the tuning of the output-scaling factor (SF) that is equivalent to the controller gain has been given the highest priority because of its strong influence on the performance and stability of the system [18]. The self-tuning mechanism is applied to PI type Fuzzy Logic Controller for simulation experiment.

In the HVAC system, the supply air pressure is regulated by the speed of a supply air fan. Increasing the fan speed will increase supply air pressure, and vice versa. The dynamics from the fan variable speed drive to the supply air pressure can modeled as a second order plus dead time. This process is well established by Bi and Cai [19]. In real application however, both fans and dampers exhibit non-linear properties for different working points, even a well-tuned PID controller may not be able to achieve a desired performance for all set points and process variations.

In the first part of this paper Self-tuning Fuzzy Logic Controller is described. The second part described the implementation of the PI type Self-tuning Fuzzy Logic Controller on a HVAC system. In the last part simulation results are presented to compare with the well-tuned PID controller and Adaptive Neuro-Fuzzy (ANF) controller.

II. DEVELOPMENT OF PI-TYPE SELF-TUNING FUZZY CONTROLLER

The basic function of the rule base is to represent in a structured way the control policy of an experienced process operator and/or control engineer in the form of a set of production rules such as

If {process state} then {control output}.

Considered a set of desired input-output data pairs:

$$[x_1^{(1)}, x_2^{(1)}; u^{(1)})], \ [x_1^{(2)}, x_2^{(2)}; u^{(2)})] \quad (1)$$

where x_1 and x_2 are inputs and u is the output. Here considered error (e) as x_1 and change of error (Δe) as x_2. The task here is