Comparative Analysis of HVAC using PID, Fuzzy and ANFIS Technique

Renu Vashisth [1]*, Naveen Kaushik [2]
[1]M. Tech. Student, Electrical Engineering
[2]Assitant Professor
HCE, Sonipat
Haryana, INDIA

***Abstract:-** The automation of industrial finishing processes in automotive industry requires accurate control of temperature and humidity of the inlet air to guarantee constant product finish quality. Industrial heating, ventilation and air conditioning (HVAC) control systems are used to maintain the required operating conditions for the finishing process even in presence of changes of the ambient air conditions. This paper presents the development of temperature and humidity control strategy for HVAC based on Fuzzy Logic Control (FLC). The goal of the FLC-based temperature control is to satisfy the convergence and equilibrium property. The simulation test results have been shown a satisfactory to control the temperature and humidity. The main objective of the report is to shed light on new this but highly promising approach of adaptive neurofuzzy interface system in control system. The system provides variation of energy consumption by changing input parameter. The stability of system is defined by settling time rise time etc.*

Keywords: HVAC, ANFIS, PID, Fuzzy Logic

I. INTRODUCTION

To ensure the comfortable air quality for humans, using the heating, ventilation and air conditioning, known as HVAC system, in the big residential and commercial center buildings is extremely important. The two main parameters related to the design of the controllers for two channels of the HVAC, temperature and humidity of the indoor air. Temperature and humidity control is important for both human comfort and the need in industry due to automation. In view of the above, this dissertation gives three intelligent controllers for controlling the temperature and humidity environment of buildings using Matlab platform.. A Control scheme for Indoor Room temperature and humidity is proposed based on the continuous monitoring of the thermal and climatic variables. The dynamic behavior of the relevant variables is determined and expressed in terms of a system transfer function. In this study, the indoor temperature control loop has been implemented using a fuzzy logic, ANFIS & then compare it with conventional PID controller. The HVAC system is designed to produce a conductive atmospheric environment for human beings or a special environment for some industrial and scientific processes. Temperature, humidity, air motion, and air purity within a space are controlled with an HVAC system. The indoor air quality of an enclosed space has a significant effect on the health and productivity of its occupants since a person may spend much time indoors. The comfort air-conditioning system is employed to produce a comfortable environment for people. Researches over many years have identified the major factors contributing to the human thermal comfort: temperature, relative humidity, air movement, and radiant effects, among which temperature and relative humidity are generally controlled. Because man is more sensitive to temperature than to humidity, most of the comfort air-conditioning systems is designed to provide relatively accurate temperature control while keeping the relative humidity floating within some larger range, which is usually defined from 30% to 60% [11].

It is estimated that, commercial buildings account for about 30% of the total electrical energy consumed in the country. Of this about 50% to 60% is consumed by air-conditioning and mechanical ventilation (HVAC) systems [32].

With the increasing consumption in HVAC system and limitations of energy resources with increasing in price from time to time, it is therefore essential to find ways to improve the efficiency of systems.

The rest of paper is design as follows. The problem statement of research work is described in section II. Modeling of HVAC System is described in section III. The complete description of ANFIS Simulation results & analysis is described section IV. The overall conclusion of research work describe in section VI.

II. Problem Statement

The essential parameters which are to be controlled independently and accurately in HVAC system is temperature and relative humidity for commercial as well as industrial applications. Central chilled water systems are often used in large-scale air-conditioning projects. The chilled water is produced in the central plant and flows through the air-handling unit (AHU), where it absorbs sensible and latent heat from the passing air. The air is cooled and dehumidified after the heat transfer.

Conventionally, the accurate control of temperature and relative humidity of the conditioned space is accomplished by cooling the air to the required specific humidity and reheating it to the desirable temperature. Undoubtedly, this method increases the energy consumption. According to heat transfer theories, the chilled water flow rate and the supply airflow rate decide the system cooling capacity jointly. Variations in the supply airflow rate result in simultaneously varying supply air temperature and humidity, which can also be changed by varying the chilled water flow rate.

The behavior of the controller has direct effect on the performance of the air-conditioning system. The objective of the control system is to adjust the plant cooling capacity to adapt to the varying heat load. PID controllers are by far the most widely used and have proven themselves to be valuable and reliable in HVAC applications [50].

Artificial intelligence, such as expert systems, fuzzy logic and artificial neural networks (ANNs), has been implemented to get better results. The origin of artificial intelligence (AI) can be traced back to the 1950s. There is no unique definition of intelligence; the most commonly accepted definition is “intelligence is the ability to perceive, understand and learn about new situations” [13]. These techniques show some advantages over the conventional controls.

In this Paper, implemented controllers like fuzzy logic and ANFIS are investigated for their use in the control of temperature and humidity in air-conditioning systems.

III. Modeling of HVAC System

In hot and humid countries, air-conditioning plants are usually employed for cooling and dehumidification purposes. A commercial chilled-water all-air system was studied in this. Experiments were conducted on this system to investigate the proposed control method. The control strategy must be analyzed theoretically prior to implementation. This chapter presents the principles of the air-conditioning system and the modeling of its main components.

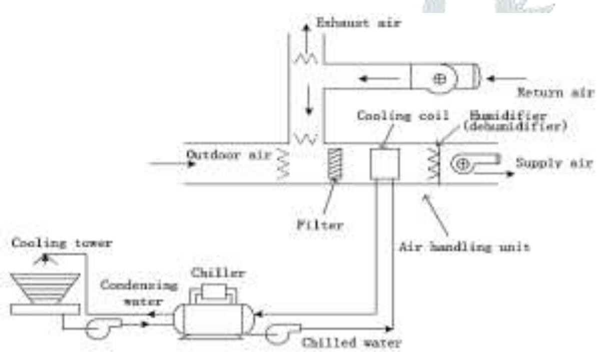

Figure 1 Schematic diagram of a chilled water air-conditioning system

Fig.1 is a schematic diagram showing the major elements of a commercial air-conditioning system. The chiller, which produces the chilled water, is the source of system cooling capacity. The chilled water is supplied to the cooling coils in the air-handling unit (AHU) where the water extracts heat from the passing air. The processed air is then supplied to the conditioned space. In this way, the space is maintained at the desired condition. Because the heat transfer between the chilled water and air occurs in the AHU, its performance directly decides the system cooling capacity.

In order to model the cooling coil, it is assumed that the air, at a flow rate of f_s enters the cooling coil at a temperature θ_m and humidity ratio W_{s1}. It is also assumed that the air within the cooling coil unit has a uniform density, of a uniform temperature θ_i and a uniform humidity ratio W_s. The chilled water at temperature θ_{ci} is supplied to the cooling coil and returns at a temperature of θ_{co}. By identifying the energy flows to and from the air-handling unit, the energy balance can be expressed as [35]:

$$C_a \frac{d\theta_s}{dt} = f_c p_w C_w(\theta_{ci} - \theta_{c0}) + \alpha_a(\theta_0 - \theta_s) + f_s p_a c_a(\theta_{si} - \theta_s) \quad (1)$$

Where

C_a = Air handling unit air thermal capacity

C_f = chilled water flow rate

P_w = density of the chilled water

C_w = chilled water specific heat

C_a = air specific heat ac

p_a = air density

α_a = unit area-integrated heat transfer coefficient

In Eq. 1, the rate of increase in energy stored in the unit is equated to the energy supplied by the chilled water and the energy added to the unit via the return air from the room and the surrounding outer surface of the unit. The mass balance equation on the water vapor is:

$$V_a \frac{dw_s}{dt} = f_s(w_{si} - w_s) \quad (2)$$

From Eq. 2, a lower supply air temperature can be achieved by increasing the chilled water flow rate or decreasing the airflow rate. Eq.3.2 implies that, by changing the supply airflow rate, the water vapor can be stored in the air-handling unit. Previous field studies have showed that lowering airflow across the cooling coil can enhance the moisture removal rates. Luxton and Shaw assessed the impact of variable air velocity and chilled water flow on the coil performance using program simulations. It was found that changes in the chilled water flow and air velocity led to great changes in the ratio of the latent heat transfer to the sensible heat transfer.

IV. Adaptive Neuro-fuzzy Interface System

It was shown that fuzzy logic could be successfully applied to room temperature and RH control. However, the fuzzy logic controller is built on linguistic rules given by human experts. Sometimes, there is not enough expert knowledge available or the initial fuzzy rules may even be incorrect. The fuzzy rules adopted for one system may not be applicable to other system. In these conditions, tuning of fuzzy controller is necessary [27]. However, tuning of fuzzy systems is not a straightforward task e.g. how to arrive at the optimal membership functions and the fuzzy rules. Neural networks have the ability of self-learning. This chapter presents a self-tuning fuzzy controller integrating fuzzy logic with neural networks. The fuzzy controller is built in a neural network structure, and the parameters of the fuzzy controller can be treated as the connecting weights in the neural network. By this means, tuning of the fuzzy system is achieved through training of the neural network.

The fuzzy logic system can be constructed with a multi-layer feed-forward neural network [17]. A schematic diagram of fuzzy neural network (FNN) architecture is shown in Fig. 2. Two input variables and one output variable are assumed in this figure. The network consists of 49 layers. There are two inputs, xi and x2, to the neural network and the output of the neural network is. X2 Nodes in the1st layer transmit input variables to the next layer directly, with unity connecting weights. Nodes in Layer 2 are membership nodes that act like membership functions. Each membership node is responsible for mapping an input linguistic variable into a possible distribution for that variable. Each node in the 3rd layer is used to perform matching of a fuzzy logic rule. Taken together, all nodes in this layer form the fuzzy rule base. The node in the last layer gives the final output.

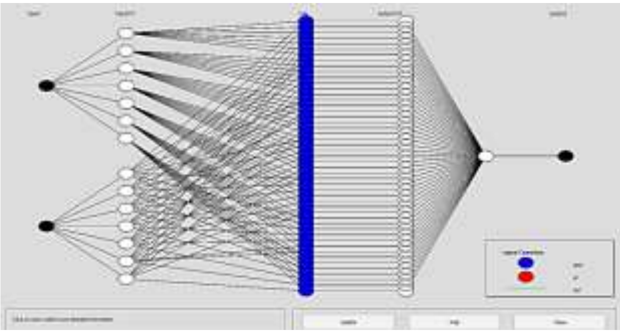

Figure 2 Matlab Simulink flow diagram of neural network

In order to ensure differentiability, the Sum-Product inference method is adopted instead of the Max-Min method and weighted sum is used in defuzzification. Define ijα as the firing strength of a rule and as the consequent of the rule, the output of the output node is then obtained from the weighted sum of its inputs.

V. Simulation & Result Analysis

In this part of the paper, we implemented a fuzzy-logic controller for the air conditioning system in commercial buildings to control both the room temperature and humidity ratio.

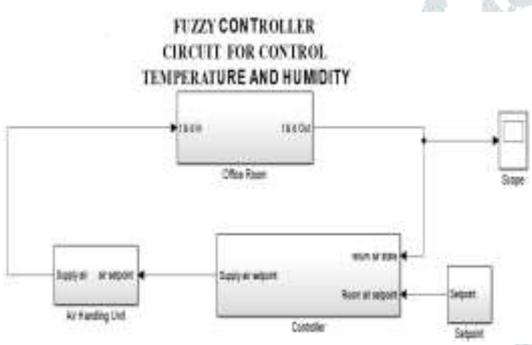

Figure 3 Matlab Simulink Block diagram of Office room temperature with fuzzy controller

Figure 3 represent the HVAC model it is used to control office Room temperature and Humidity of office. For understanding this HVAC block Diagram

Set point: Figure 3 Matlab Simulink Block diagram of set point to maintain temperature and humidity, set point is used to set temperature of office room and controller maintain its temperature in block diagram we can see set the temperature at 20'c and humidity 9 this set value helps to controller as a reference value

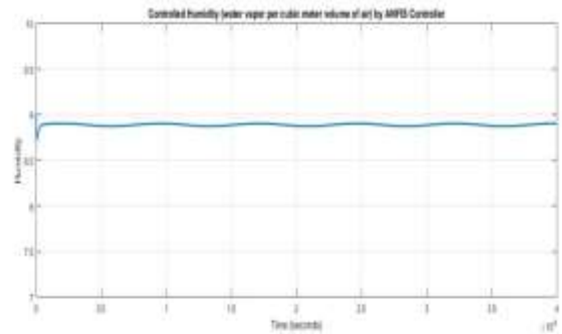

Figure 4 Controlled Humidity graph by adaptive neural network fuzzy interface system

Figure 4 Controlled Humidity graph by adaptive neural network fuzzy interface system represents vertical axis in humidity and horizontal axis is in time in seconds. Now Humidity is set in 8.85 by adaptive neuro fuzzy interface system. It have very less steady state error it reach to set value easily compare to other control technique.

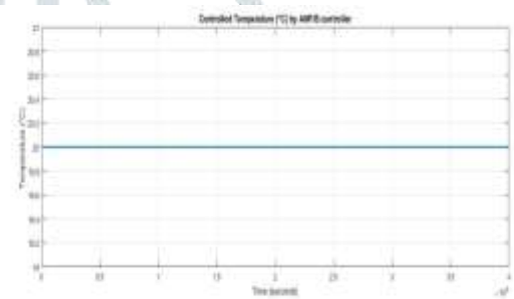

Fig 5 Controlled Temperature graph by adaptive neural network fuzzy interface system

Fig 5 represent Controlled Temperature graph by adaptive neural network fuzzy interface system represents vertical axis in temperature in degree Celsius and horizontal axis is in time in seconds. Now temperature is set in 20'c by adaptive neuro fuzzy interface system. It have very less steady state error it reach to set value easily compare to other control techniques.

Table 1 and 2 shows the comparative analysis of PID, Fuzzy and ANFIS controller techniques which are used to control Temperature and Humidity control of office buildings.

Table 1 Temperature Control using PID, Fuzzy and ANFIS controller

Sr .No.	Parameters	PID Controller	Fuzzy Controller	Neuro Fuzzy Controller
1.	Overshoot	30%	6%	5%
2.	Rise Time	20 Secs	5 Secs	5 Secs
3.	Steady State Error	10%	2%	2%
4.	Peak Time	30 Secs	4 Secs	3 Secs

Table 2 Humidity Control using PID, Fuzzy and ANFIS controller

S.No.	Parameters	PID Controller	Fuzzy Controller	Neuro Fuzzy Controller
1.	Overshoot	40%	10%	4%
2.	Rise Time	40 Secs	15 Secs	5 Secs
3.	Steady State Error	40%	10%	4%
4.	Peak Time	50 Secs	20 Secs	6 Secs

From comparative analysis, in case of temperature control, it is found out that ANFIS controller is better than other intelligent control techniques due to improvement in certain parameters like overshoot is 5% from 6% and peak time is 3 sec from 4 sec in comparison to Fuzzy controller.

In case of humidity control, it is found out that ANFIS controller is better than other intelligent control techniques due to improvement in certain parameters like overshoot is 4% from 10%, rise time is 5 sec from 15 sec, steady state error is 4% from 10% and peak time is 6 sec from 20 sec which is less than Fuzzy controller and much more less than PID controller for temperature control of office building. So ANFIS controller is the best intelligent control technique in comparison to PID and Fuzzy controller for temperature and humidity control of office buildings.

VI. Conclusion

In this dissertation, firstly experimental and theoretical analysis of the HVAC system at commercial building is done, and then we implemented the intelligent control techniques for temperature and humidity control of office building. This adaptive scheme was firstly used to build the PID controller for controlling the temperature and humidity control of office building but found some variations in set point. Furtherance improvement is done using artificial intelligent control techniques such as Fuzzy controller and ANFIS controller for controlling the temperature and humidity control of office building. ANFIS controller gave better results as comparison to other intelligent control technique Fuzzy controller with the improvement in peak overshoot, rise time, steady state error and peak time.

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