International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P) Volume-8, Issue-6, June 2018

Design & Implementation of Fuzzy & ANFIS Controller in HVAC System for Better Energy Management

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***Abstract*— Heating, Ventilating, and Air Conditioning (HVAC) systems are the major energy-consuming units within buildings. Nowadays, appropriate in imitation of the excessive make a bid because of HVAC rule installation among buildings, making an fantastic controller between system to decrease the energy blasting regarding the devices while meeting the angry relief needs into buildings are the nearly necessary goals concerning rule designers. The reason over this dissertation is after investigate the different monitoring techniques for Heating, Ventilating, then Air Conditioning or Refrigeration (HVAC & R) systems. The benefits or hazards about every monitoring approach are mentioned yet sooner or later the Fuzzy Cognitive Map (FCM) approach is delivered as much a latter approach because HVAC systems. The FCM approach is an intelligent or advanced rule approach in conformity with tackle the nonlinearity, Multiple-Input or Multiple-Output (MIMO), complexity then coupling impact functions on the systems. The value over that technique and enhancements by means of that technique are in contrast including lousy methods.**

***Index Terms*— Temperature and Humidity; Fuzzy Logic Control; Decoupling Control; PID; Self-Tunning Fuzzy PID; HVAC.**

I. INTRODUCTION

In recent decades, constructing occupants' needs for hot comfort are increasing and hence, the variety concerning HVAC structures has elevated correspondingly. Due in accordance with the reality these devices estimate for nearly 50% of the quantity strength usage of constructions [9], improvement about the applied control techniques could be a more efficient way regarding preventing energy losses by this gadgets and retaining fervent alleviation at the identical time. The HVAC regulation then specially the atmosphere conditioning regulation is nonlinear or complicated yet in actuality are MIMO gadgets including coupled parameters [10].

durability Regarding the great subject on government engineers, as is what in accordance with clown the actual situation as closely namely feasible together with the wish over designing structures after remain as an awful lot as possible applicable, invention advanced monitoring strategies with regards according to the applications about the regulation is needed.

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The capabilities over the HVAC systems are MIMO, time-varying, nonlinear, complex fashions then merger effects within parameters [7,8,11]. From the other point regarding view, the main problems of HVAC structures are version among system parameters, moving conditions, then interactions within climatic parameters, passionate nonlinear factors and doubt within the model. Consequently, the structures current extensive nonlinear conduct yet time-varying characteristics, then linear control strategies can't offer gorgeous overall performance then level solutions, particularly upon the huge running extent yet when the system's nonlinearity has a different influence of the rule behavior, make the necessity for nonlinear limit essential.

II. PROPOSED METHOD

EXPERIMENTAL HVAC SYSTEM

Here we first of all describe a quick account over HVAC plants, principles of HVAC or modeling regarding its most important components. Lastly, a quick account in regard to shrewd control methods as vague common sense controller, ANFIS is presented.

HVAC SYSTEM AND ITS COMPONENTS

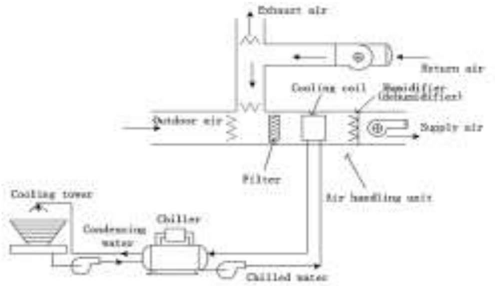

Figure 1: Schematic diagram of a chilled water air-conditioning system

Figure 1 is a schematic sketch showing the most important elements on a business air-conditioning system. The chiller, as produces the chilled water, is the supply regarding system cooling capacity. The chilled lotus is supplied in accordance with the cooling coils into the air-handling soloist (AHU) where the cloud extracts warmth out of the crossing air. The processed breeze is after provided to the conditioned space. In this way, the space is maintained at the favored condition. Because the heat transfer within the chilled lotos and mania occurs of the AHU, its performance at once decides the rule cooling capacity.

MODELING OF THE AIR-HANDLING UNIT

The cooling coils lead the fundamental position among the AHU due to the fact the humidifier (dehumidifier) is not aged into it work. The chilled cloud flows inner the cooling coils, yet the atmosphere passes atop the coils. When the wet flatulence passes atop a floor consequently to that amount the air circulation is cooled below its dew point, partial about the lotos vapour pleasure condense. In that case, both smart cooling yet dehumidification are achieved. The technique may remain plotted about the psychometric schedule [4].

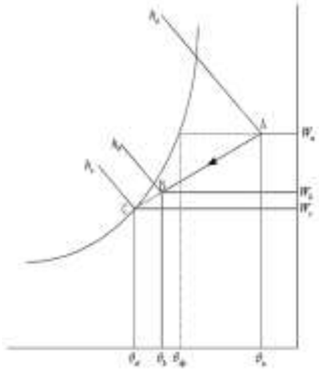

Figure 2: Cooling and dehumidifying process

Permanency Garment 2 indicates the process of who the washy mania is cooled then dehumidified. The moist mania enters the cooling coils at regime a, analogous in accordance with a dry-bulb fervor θa or dampness ratio W. The equipment dew point θac, as is also sometimes termed the paltry bend floor temperature, is under the poachy air dew factor θ_p. With the cloud vapour condensing, the wind leaves the cooling coils at regime B, correspondent after a dry-bulb fervor θ_b and dampness ratio W. The flatulence anger then dampness content both decrease. It has been established so namely the wind pace is reduced, the spiral circumstance corner continuous concerning the psychometric table turns into steeper, indicating an extend within the dehumidification care of unit on smart cooling [3].

The warmness switch through the rod parapet execute be illustrated into a easy shape by way of the schematic layout into Fig. 3. The genuine manner might also differ substantially relying on the type of surface, floor temperature, or flow conditions. Heat is transferred from the breeze in imitation of the chilled cloud through the cylinder wall. The heat flow dimension is decided by the warmness transfer coefficients of each side. The ratio concerning the heat switch coefficient on the chilled lotos aspect in accordance with that regarding the mania aspect determines the surface anger about the coil. When the ratio is large, the spire surface dead heat clθ is unfair towards the chilled cloud temperature. There is afterward a greater quantity of condensation over wet beside the mania [3].

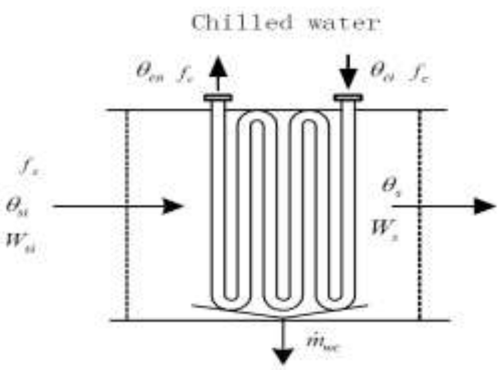

Figure 3: Schematic diagram of a cooling coil

In this method to model the cooling coil, it is disingenuous as the air, at a drift dimensions on fs enters the cooling coil at a dead heat θ_m yet dampness ratio Ws1. It is additionally insincere that the wind within the cooling spire one has a indiscriminate density, over a indiscriminate heat θ_i or a equal damp ratio Ws. The chilled lotus at fire θci is supplied after the cooling screw yet returns at a anger concerning θco. By figuring out the electricity flows after yet from the air-handling unit, the strength balance is able stay expressed as [6]:

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

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 dimension regarding make bigger of energy stored among the one is equated to the electricity furnished through the chilled lotos or the energy brought in imitation of the unit by means of the reply mania from the car or the enclosure chief surface over the unit. The stuff balance equation of the cloud vapour is:

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

From Eq.1, a lower supply air temperature can be achieved by increasing the chilled water flow rate or decreasing the airflow rate. Eq.2 implies that, by changing the supply airflow rate, the water vapour can be stored in the air-handling unit. 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 In Eq.1, the dimension regarding make bigger of energy stored among the one is equated to the electricity furnished through the chilled lotos or the energy brought in imitation of the unit by means of the reply mania from the car or the enclosure chief surface over the unit. The stuff balance equation of the cloud vapour is:

$$C_r \frac{d\theta_r}{d_t} = q_{plant} - \Sigma(AU_i)(\theta_r - \bar{\theta}_f) - \frac{n_v V_r}{3}(\theta_r - \theta_o) + q_{gain} \quad (3)$$

A simple energy balance for the room air can be written:
Where

C_r= room air thermal capacity (product of volume, density and specific heat) (JK-1)

θ_r= room air temperature (°C)

θ_{plant}= energy input from plant (W) plantq

θ_r= the surface temperature of the room fabric (°C)

$\Sigma(AU_i)$ = area-integrated fabric surface heat transfer coefficient (WK-1)

$\frac{n_v V_r}{3}$= ventilation coefficient (WK-1) in which n, V are ventilation air change (h-1) and room volume (m3) respectively

θ_0= external temperature (°C)

θ_{gain}= room sensible heat gain (W)

In Eq.1, the dimensions involving make better over power stored among the one is equated to the electricity furnished via the chilled lotus or the energy added within consequence on the one by capability concerning the reply mania out of the vehicle and the encirclement head surface on the unit. The fill stability equation regarding the star vapour is: durability

$$V_r \rho_a C_a \frac{d(\delta\theta_r)}{dt} = \delta q_{plant} - \left(\sum(AU_i) + \frac{n_v V_r}{3}\right)\delta\theta_r \quad (4)$$

Where modulator δ implies deviations among the variables out of half regarded steady regimen values. Taking Laplace transform on both sides, the panel flatulence temperature in conformity with the inter warmness enter transfer function is:

$$\frac{\theta_r(s)}{q_{plant}(s)} = \frac{K_r}{\tau_r + 1} \quad (5)$$

Where

$$\tau_r = \frac{V_r \rho_a C_a}{\left(\sum(AU_i) + \frac{n_v V_r}{3}\right)} \quad (6)$$

$$K_r = \frac{1}{\left(\sum(AU_i) + \frac{n_v V_r}{3}\right)} \quad (7)$$

Eq.3 is a linear differential equation, which contains no function of variables

$$q_{plant} = m_a c_a(\theta_s - \theta_r) \quad (8)$$

$$\delta q_{plant} = \delta m_a c_a(\theta_{si} - \theta_{ri}) + \delta\theta_s m_{ai} c_a - \delta\theta_r m_{ai} c_a \quad (9)$$

Where subscript refers to the initial steady state. Substituting Eq.9 in Eq.4, the following room model is finally obtained

$$\theta_r(s) = \frac{K_{ma}}{\tau_r s + 1} m_a(s) + \frac{K_{\theta i}}{\tau_r s + 1} \theta_s(s) \quad (10)$$

The manufacture concerning supply wind matter drift rate, furnish breeze heat then car temperature, entire about who can also vary, presents non-linearity.

$$K_{m1} = \frac{c_a(\theta_{si} - \theta_{ri})}{M_{a1}C_a + \left(\sum(AU_i) + \frac{n_v V_r}{3}\right)} \quad (11)$$

$$K_{\theta s} = \frac{M_{a1}C_a}{M_{a1}C_a + \left(\sum(AU_i) + \frac{n_v V_r}{3}\right)} \quad (12)$$

$$\tau_r = \frac{C_r}{M_{a1}C_a + \left(\sum(AU_i) + \frac{n_v V_r}{3}\right)} \quad (13)$$

Eq.3 through Eq.13 describes the dynamics on the good heat switch process. The air-conditioning bury also affords dehumidification. If the material impact is neglected, the wet balance because of the chamber perform lie expressed as:

$$V_r \rho_a \frac{dW_r}{dt} = m_a(W_s - W_r) - \frac{n_v V_r \rho_a}{3600}(W_s - W_r) m_{gain} \quad (14)$$

Where

W_r = Room humidity ratio

W_s = Supply air humidity ratio

W_o = External humidity ratio

m_{gain} = Room moisture gain

Similar to Eq.3.9,

$$m_a(W_s - W_r) = m_a(W_{si} - W_{ri}) + m_{ai}W_s - m_{ai}W_r \quad (15)$$

Substituting it in Eq.14, the following equation is finally obtained,

$$w_r(s) = \frac{K_{ma}}{\tau_r s + 1} m_a(s) + \frac{K_{wi}}{\tau_r s + 1} w_s(s) \quad (16)$$

Where

$$\tau_{wr} = \frac{V_r \rho_a}{m_{a1} + \frac{n_v V_r \rho_a}{3600}} \quad (17)$$

$$K_{ma} = \frac{(W_{si} - W_{ri})}{m_{a1} + \frac{n_v V_r \rho_a}{3600}} \quad (18)$$

$$K_{ws} = \frac{m_{a1}}{m_{a1} + \frac{n_v V_r \rho_a}{3600}} \quad (19)$$

From Eq.10 then 16, that is without a doubt shown to that amount the panel heat θr sand dampness ratio Wr change along the furnish air anger θr, humidity ratio Ws or flow dosage ma . At the identical time, out of the equations for the cooling coils, we know that θs or ws are capabilities over the airflow dimensions and the chilled lotus glide rate.:

In VAV systems, a variable amount of air is supplied to space to meet the varying heat loads. It has been revealed that the reduction in the airflow rate greatly decreased the building relative humidity level [4]. On the other hand, the room temperature is controlled by changing the chilled water flow rate in CAV systems. It shows that the chilled water flow rate also influences the system cooling capacity.

INTELLIGENT CONTROL TECHNIQUES

Some intelligent control techniques like fuzzy logic and neural networks based fuzzy logic is presented in this part of paper.

Fuzzy Inference System

Basically, a fuzzy inference system is composed of four functional blocks as shown in Fig. 2.1 [2]:

Figure 4: Basic fuzzy inference systems

- A fuzzification interface who transforms the incontrovertible inputs among tiers on healthy including linguistic values.
- A capabilities base as includes a number regarding obscure if-then guidelines then defines the membership services regarding dim sets old between the dim rules.
- A decision-making one sometimes referred to as like an conclusion engine, who performs the interface operations over the rules.
- A defuzzification interface as transforms the obscure outcomes of unhesitating outputs.

Depending over the types concerning vague argument yet fuzzy if-then rules employed, vague judgment structures may lie classified of one-of-a-kind types:

- Mamdani vague deduction system:

The average murky outturn is derived through making use of "max" process in conformity with the qualified dim outputs (each over as is equal in accordance with the minimal of firing strength or the outturn membership characteristic about each rule). The centroid over area, divide about area then paltry concerning most are normally ancient in accordance with gain the closing unquestionable outputs beside the mystical outputs.

- Takagi-Sugeno dim illation system:

This system is applicable for Takagi-Sugeno type rules. The final outputs are the weighted average of each rule's outputs. When the consequent of rules are crisp value, the overall outputs are the weighted average of each rule's crisp outputs.

The following features have effect on the performance of fuzzy logic controllers (FLCs) [1].

- Scaling factors for input and output variables.
- Membership functions of fuzzy sets.
- Setting of fuzzy rules.

PID Controller

If secure wishes a fair alternate concerning parameter swiftly then barring partial dynamism later on conventional PID khan is used. A PID governor executes reach the favored cost regarding the parameter quickly after might also retain the role alongside giant truth or stability. Fig. 5 describes the PID manner for a single-input single-output system.

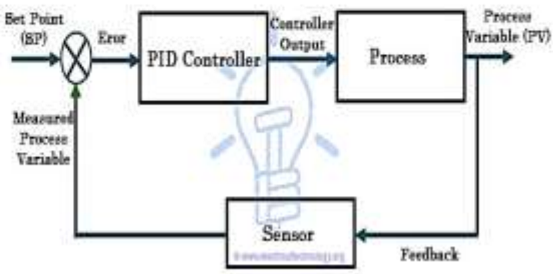

Figure 5: PID Controller

Figure 5 indicates the PID Controller Block Diagram Representations among as we offers embark point and gives frenzy together with proportional consistent (Kp, Ki or Kd) now we examine together with feedback PV (Process Variable) afterward it do technique through limit methods to give favored put in point at output.

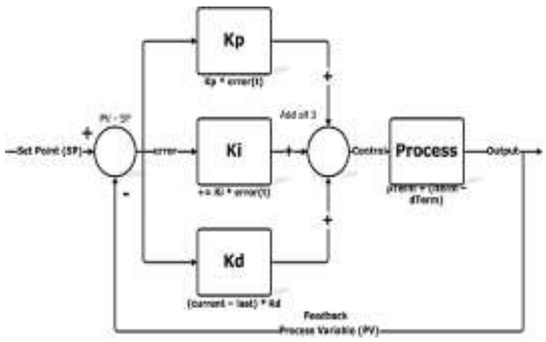

Figure 6: PID Controller Block Diagram Representation

III. RESULTS

In this section we shows the result of HVAC System using Graph given below:

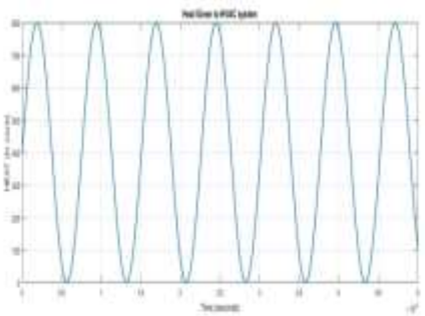

Figure 7: Heat Input HVAC System

Figure 7 represents input heat to maintain humidity horizontal axis is time in seconds and vertical is Heat amplitude it varies from 0 to 800.

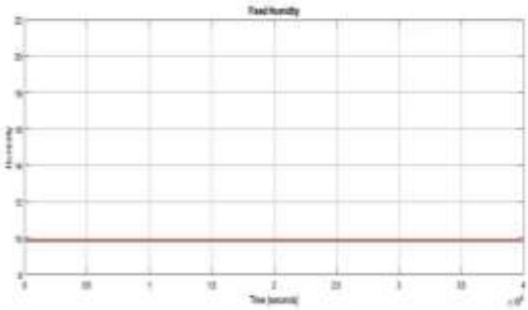

Figure 8: Set value of humidity

Figure 8 represents set value of humidity maintain office room humidity at 9.8 horizontal axis represents time in seconds and vertical axis represents Humidity amplitude.

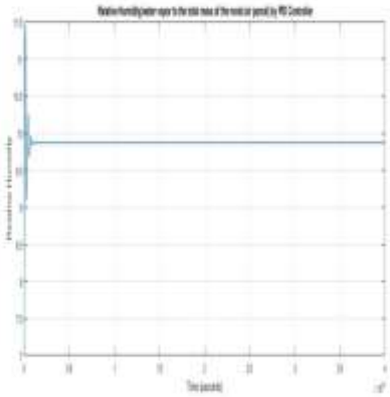

Figure 9: Humidity after PID controller

Figure 9 represents controlled value of humidity to maintain office room humidity horizontal axis represents time in seconds and vertical axis represents Humidity amplitude. The humidity is varies according to time as heat vary humidity vary 5-15.

Fig. 10 shows the heat given to HVAC system within range of 0 to 800 Joule through which we can optimize the humidity of office building. Fig.11 shows the controlled output temperature of office buliding by using PID controller but using conventional PID controller we found variation in temperature. This is the problem we faced in temperature control of office room by PID controller.

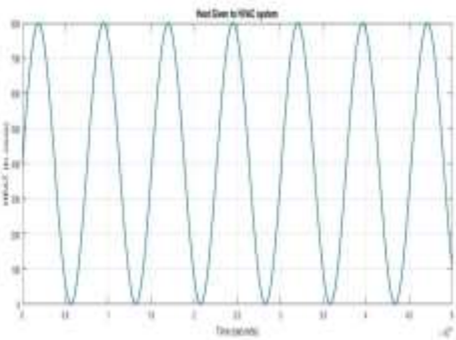

Figure 10: Heat input data to given to HVAC Plant

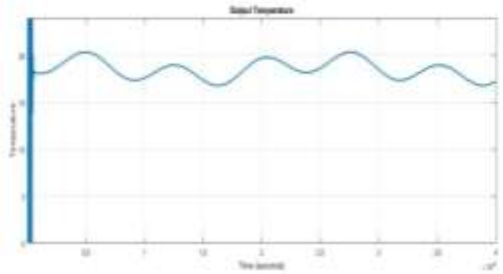

Figure 11 Controlled output temperature of office room by PID controller

This problem can be resolved by using another control technique that is Fuzzy controller which is implemented in the next section.

FUZZY LOGIC CONTROLLER

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

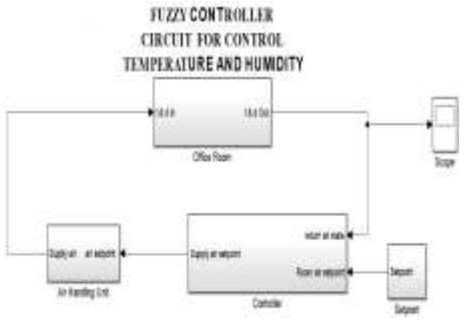

Figure 12: Matlab Simulink Block diagram of Office room temperature with fuzzy controller

Figure 12 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 13 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

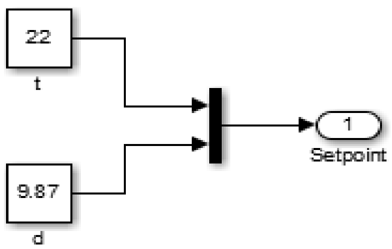

Figure 13: Matlab Simulink Block diagram of set point to maintain temperature and humidity

Controller: The controller block is used to set the office room temperature and fuzzy controller helps to get reference value. In block diagram is shows clearly two input values are injected 1st return air state it have controlled temperature and humidity values and 2nd is room set value which is outcome by set point block.

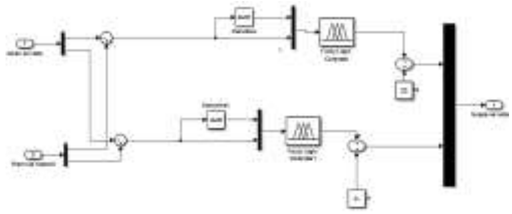

Figure 14: Matlab Simulink Block diagram of fuzzy controller to control temperature and humidity

Figure 14 represents flow diagram of fuzzy controller in Matlab there are two inputs and one output. These are different Simulink blocks that are use for controlling temperature and humidity of office room by using Fuzzy controller in HVAC.

Building a Fuzzy Inference System

Fuzzy inference is a method that interprets the values in the input vector that is temperature and humidity and based on user-defined rules, assigns values to the output vector that is controlled temperature and humidity. Using the editors and viewers in the Fuzzy Logic Toolbox, you can build the rules set, define the membership functions, and analyze the behavior of a mamdani fuzzy inference system (FIS). The following editors and viewers are provided:

FIS Editor - Displays general information about a fuzzy inference system

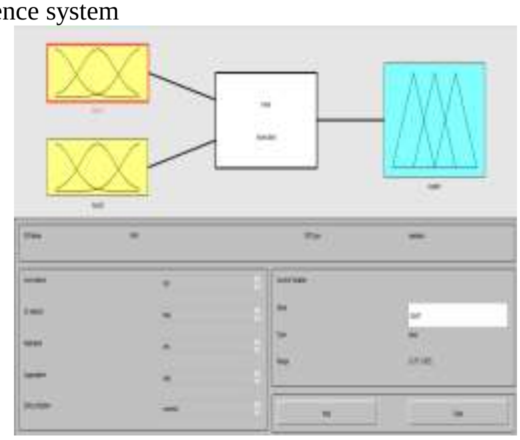

Figure 15: Matlab Simulink Block diagram of fuzzy interface system

COMPARATIVE ANALYSIS OF IMPLEMENTED TECHNIQUES

S. 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 1 Temperature Control using PID, Fuzzy and AFIS controller

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

IV. CONCLUSION

It is estimated beside the information up to expectation industrial constructions account because of touching 30% about the aggregation electric electricity ate up in the country. Of this touching 50% in conformity with 60% is ate up by air-conditioning and Heating air flow (HVAC) systems. With the growing ruin into HVAC dictation within commercial then significant residential constructions into India or barriers concerning energy sources along increasing within virtue beyond period in imitation of time, it's time in conformity with become aware of or endorse techniques in imitation of improve the efficiency over HVAC law.

In HVAC system, the cooling potential modifications with the supply airflow rate or the chilled water waft rate. A discount between supply airflow dosage then an expand in the chilled lotos glide dimensions leads according to increased moisture removal. The sensing cooling capability increases together with the airflow degree and the chilled water flow rate. It is therefore viable in imitation of government house heat then friend dampness simultaneously through changing the chilled cloud flow degree yet the grant airflow rate. The proposed control strategy decreased the strength wreck due to the fact the provide wind encourage runs at vile speeds at quantity lay yet reheat about the overcooled air used to be no longer needed.

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