

# Poultry House Temperature Control Using Fuzzy-PID Controller

Aborisade, David O. <sup>#1</sup>, Oladipo Stephen <sup>\*2</sup>

<sup>\*1</sup>Associate professor, <sup>\*2</sup>PG student

<sup>1,2</sup>Electronic/Electrical Engineering Department, Ladoko Akintola University of Technology

P.M.B. 4000, Ogbomoso, Oyo-State, Nigeria

**Abstract**— Temperature control of poultry house within thermal neutral zone of poultry birds is essential in order to reduce their mortality and increase production. The most advanced method to control the highly complex and nonlinear behaviour of the poultry house temperature, is fuzzy logic. On the other hand, PID controllers are used in most of poultry house due to its functional and structural simplicity. This paper presents a method of controlling the poultry house temperature by the combined action of both Fuzzy and PID controllers. In the design, fuzzy controller uses the structure of two inputs and three outputs. Deviation  $e$  and deviation rate  $\dot{e}$  are the inputs of the system. These are translated into a fuzzy form, fuzzy processed according to IF...THEN rules to arrive at a single outcome value and then defuzzified to get accurate values of  $k_p, k_i, k_d$  which are used to auto-tune PID controller to control the poultry house temperature. The performances of the Fuzzy-PID based poultry house temperature control scheme during hot weather are compared with the classical PID controller. The results show that the Fuzzy-PID scheme is able to control the poultry house temperature more effectively in terms of both the steady-state error and the settling time than that of PID controller.

**Keywords**—Poultry house temperature, Fuzzy-PID control, Defuzzification.

## I. INTRODUCTION

The study of birds comfort in a poultry house has consumed the efforts of many poultry farmers over the decades. In general, birds comfort involves both physiological and psychological factors, many of which are directly related to the aggregate of characteristics that are intrinsic to the birds.

A comprehensive investigation of studies has revealed that comfort satisfaction of poultry birds can be improved by dynamically monitoring the parameters such temperature, relative humidity, and solar radiation in the poultry house [1, 2]. While it good to control all the above factors, economic considerations have dictated the control of the most important single factor, namely temperature.

High poultry house temperature can have a severe impact on poultry performance. Production efficiency can be affected long before the temperature reaches a thermal neutral zone of the poultry bird. The body temperature of a bird normally runs between 39.4°C and 40°C. The thermal neutral zone which allows adult chickens to maintain their body temperature is between 18°C and 23.9°C [3], while for adult broilers it is between 26°C and 27°C [4]. If the poultry house temperature

is below the thermal neutral zone of the bird, energy from the feed will be used to generate heat rather than for growth and development. If the temperature is above this zone, heat must be lost in some way; this tends to result in reduced feed conversion efficiency [5].

Traditional ways of controlling poultry house temperature within the thermal neutral zone of the bird include the followings; use of curtains, reduction in energy content of the feed intakes during the heat period, usage of fan, spraying of cold water on their bodies and putting of ice into their water. All these traditional means of controlling poultry house temperature are inefficient, time consuming, tedious and require a continuous monitoring [6]. Hence, most of the poultry farmers depend on better control techniques to reduce bird mortality and increase poultry birds' production.

Although proportional-integral-derivative (PID) controllers are widely used advanced method in the process industry, their effectiveness is often limited due to poor tuning. The manual tuning of PID controllers, which requires optimization of three parameters, is a time-consuming task. To address this difficulty, much effort has been invested in developing systematic tuning methods [7]. Reviews of these methods are given in [8] and the survey paper [9]. Many of these methods are ineffective in the temperature control system with non-linear, time-varying and time-delay characteristics.

Control technique which based on fuzzy logic is alternative to conventional control method. It doesn't need the precise mathematical model of the controlled object, and only depends on the experience, knowledge and manipulate data of operators. It is suit for controlling Nonlinear Time-Varying delays system [10, 11]. The most significant advantage of fuzzy controller is its low sensitivity to plant parameter variations. The application of fuzzy logic in tuning of PID parameters is a powerful strategy to facilitate fast convergence to the optimal gain values, and to protect the system against incorrect gain changes. Numerical simulations in tuning of PID controller based on fuzzy logic approach for the poultry temperature control demonstrate the effectiveness and robustness of optimization method.

The remainder of this paper is organized as follows. Sections II and III describe the mathematical modeling of dynamic systems temperature control of a poultry house and structure of Fuzzy-PID hybrid control system, respectively. Simulation results are shown in section IV. Finally the conclusion follows in section V.

II. MATHEMATICAL MODEL

This section presents the mathematical modelling of dynamic systems temperature control of a poultry house. The working principle is governed by the laws of thermodynamics [12, 13]. These laws describe the different behaviours of energy in air, liquids and solids. The equation describing the first law of thermodynamics is

$$Q_{in} - Q_{out} = \frac{d(Q)}{dt} \tag{1}$$

where  $Q_{in}$  is the energy entering the poultry room space,  $Q_{out}$  is the energy leaving the space, and  $d(Q)/dt$  is the rate of change of the stored energy. The energy  $Q$  of air is defined by

$$Q = M \times C_p \times (\Delta t) \tag{2}$$

where  $M$  is the mass of the air and defined as  $(V_{air} \times \rho_{air})$ ,  $C_p$  is the specific heat constant, and  $\Delta t$  is the room temperature differential which is equal to  $\frac{d(T_{air})}{dt}$ .

Considering the following five types of heat that makes the changes of poultry house temperature namely heat gain from the air-conditioner ( $Q_{aircon}$ ), heat gain from opening the window ( $Q_{airflow}$ ), heat gain due to difference in temperature between inside and outside through glass window only ( $Q_{dth}$ ), heat gain due to solar radiation ( $Q_{sr}$ ), and the sensible heat gain and latent heat gain by birds ( $Q_b$ ). Therefore, the dynamic poultry house temperature equation is generated as

$$\sum Q_{all} - Q_{out} = \beta \frac{d(T_{ph})}{dt} \tag{3}$$

where  $\sum Q_{all} = Q_{aircon} + Q_{airflow} + Q_{dth} + Q_{sr} + Q_b$  and  $T_{ph}$  is poultry house temperature.  $\beta$  is define as

$$\beta = \rho_{air} V_{ph} C_p \tag{4}$$

where  $\rho_{air}$  is air density,  $V_{ph}$  is poultry house volume, and  $C_p$  is specific heat capacity of the house air.

The values of each heat equation in (3) are thus computed as follows

$$Q_{aircon} = 1.08 \times CFM (T_{sa} - T_{ph}) \tag{5}$$

where  $CFM$  is air volume flow and  $T_{sa}$  is setting temperature of air-conditioner.

$$Q_{airflow} = V_{airflow} C_p \rho_{air} (T_{So} - T_{ph}) \tag{6}$$

where  $T_{So}$  is the supplied outside temperature and  $V_{airflow}$  is the ventilation rate required to remove heat from the occupied space computed as

$$V_{airflow} = A_{op} C_d V_{air} \tag{7}$$

where  $A_{op}$  is the surface area of window opening,  $C_d$  is effectiveness of air, and  $V_{air}$  denote air velocity leaving the opening.

$$Q_{dth} = U_g A_g (T_{out} - T_{ph}) \tag{8}$$

where  $U_g$  is  $U$  – value for glass and  $A_g$  is the surface of glass window.

$$Q_{sr} = F_C F_S A_g q_{sg} \tag{9}$$

where  $F_C$  is air node correction factor,  $F_S$  is shading factor for double glazing glass, and  $q_{sg}$  is cooling load.

$$Q_b = (n \bullet shg \bullet clf) + (n \bullet lhg) \tag{10}$$

where  $n$  is the number of birds in the poultry,  $shg$  is sensible heat gain by the birds,  $clf$  is cooling load factor for the birds and  $lhg$  is latent heat gain by the birds.

$$Q_{out} = M \times C_p \times (T_{ph} - T_{air\ leaving\ ph}) = 0 \tag{11}$$

since  $T_{ph} = T_{air\ leaving\ ph}$ .

Combining equations 3, 5, 6, 8, 9, and 10, an equation of a single zone poultry house temperature is written as follows:

$$T_{ph} = \frac{1}{\kappa V_{ph}} \int [Q_{sum} + \kappa V_{airflow} (T_{So} - T_{ph})] dt \tag{12}$$

where  $Q_{sum} = Q_{aircon} + Q_{sr} + Q_b + Q_{dth}$  and  $\kappa = C_p \rho_{air}$ .

III. FUZZY- PID CONTROLLER

The structure of Fuzzy-PID hybrid control system is shown in Figure 1. Combining Fuzzy control with PID control will enable a process to reach a predetermined set point in the shortest time, with the minimum of overshoot and undershoot during power-up or external load disturbance.

In the design, fuzzy controller uses the structure of two inputs and three outputs. Deviation  $e$  and deviation rate  $\dot{e}$  are the inputs of the system. Once the fuzzy controller receives the input data, it translates it into a fuzzy form and fuzzy processed according to IF...THEN rules. The controller evaluates the table of fuzzy control rules to arrive at a single outcome value and then proceeds on defuzzification process to get accurate values of  $k_p, k_i, k_d$  which are the inputs of PID controller.

Mamdani’s fuzzy inference method is used in the system with two inputs and one output. A membership function is a curve that defines how each point in the input space is mapped to a membership value (on degree of membership) between 0 and 1. In this case, the triangle membership function is used for all variables shown in Figure 2 and 3. The physical domain of the inputs ( $e$  and  $\dot{e}$ ) are all normalized in the interval of  $[-1, 1]$  and that of the outputs ( $k_p, k_i, k_d$ ) is  $[0, 1]$ . The linguistic labels used to describe the fuzzy sets were ‘Negative Big’ (NB), ‘Negative Small’ (NS), ‘Zero’ (ZE), ‘Positive Small’ (PS), ‘Positive Big’ (PB). The output is determined depending on the defined rule base of  $e$  and  $\dot{e}$ , as indicated in Tables 1-3 for  $k_p, k_i$  and  $k_d$  respectively with the aim of minimizing the error.

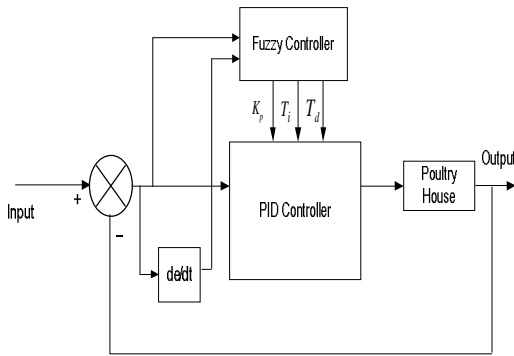


Fig. 1 Basic structure of poultry house with controller

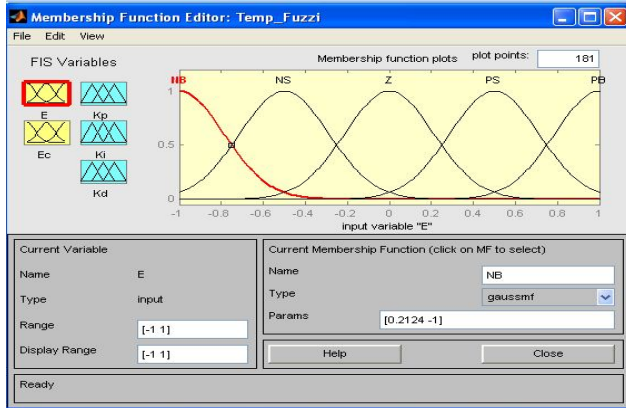


Fig. 2 The membership functions for the inputs  $e$  and  $\dot{e}$

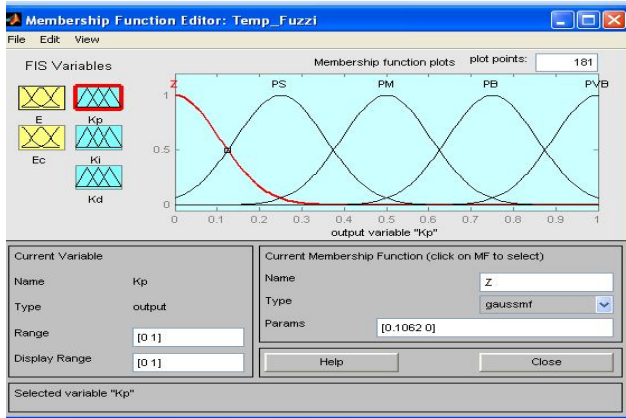


Fig. 3 Membership functions for  $k_p, k_i$  and  $k_d$

Table 1  
The rule base for  $k_p$

$e$	$\dot{E}$				
	NB	NS	Z	PS	PB
NB	PVB	PVB	PVB	PB	PM
NS	PVB	PVB	PB	PB	PM
Z	PB	PB	PM	PS	PS
PS	PM	PS	PS	PS	PS
PB	PS	PS	Z	Z	Z

Table 2  
The rule base for  $k_i$

$e$	$\dot{E}$				
	NB	NS	Z	PS	PB
NB	PVB	PB	PM	PM	PM
NS	PVB	PB	PB	PM	PS
Z	PM	PS	Z	Z	Z
PS	PM	PM	PS	Z	Z
PB	PS	Z	Z	Z	Z

Table 3  
The rule base for  $k_d$

$e$	$\dot{E}$				
	NB	NS	Z	PS	PB
NB	Z	Z	PS	PS	PB
NS	Z	Z	Z	Z	PS
Z	Z	Z	Z	PS	PB
PS	PS	PS	PS	PB	Z
PB	Z	Z	Z	PS	PB

The final output value from the Fuzzy-PID hybrid control system depends on the defuzzification method used to compute the outcome values corresponding to each label. The defuzzification process examines all of the rule outcomes after they have been logically added and then computes a value that will be the final output of the fuzzy controller. Defuzzification adopts weighted average method. Weighted average method gets the representative point, which is the center of the area made by fuzzy membership function curve and the abscissa. Theoretically, it should calculate the center of gravity of a series of points within the output scope. This is expressed mathematically as:

$$\bar{U} = \frac{\sum_{i=1}^n u_i \mu_u(u_i)}{\sum_{i=1}^n \mu_u(u_i)} \quad (13)$$

where,  $u_i$  and  $\mu_u(u_i)$  are the fuzzy output in counts for labels and the fuzzy grade level for levels  $i$ . respectively.

#### IV. EXPERIMENTAL RESULTS

In this work, the poultry house temperature is controlled by conditioned supply air. The supply air handling unit consists of motorized dampers, heating coils, cooling coils, and supply air fans to maintain in-house temperatures within the birds' comfort zone. Table 4 summarizes the parameters and values that are used in the simulation of the proposed temperature control system during hot weather.

Mathematical modeling of dynamic systems temperature control in a poultry house as well as the controllers has been

developed and implemented in MATLAB/Simulink. The simulink model of both classical PID and Fuzzy-PID controllers is shown in Figure 4. The three-dimensional view of  $k_p$ ,  $k_i$  and  $k_d$  are shown in Figure 5.

For numerical simulation, the desired poultry house temperature has been set at 26.5°C which falls within the thermal neutral zone for adult broilers. Figure 6 shows the performance comparison of the simulation result of the Fuzzy-PID and classical PID controller based temperature control of the poultry house during at outside temperature of 38°C and 30°C. It is clearly seen from this figure that by using fuzzy control for tuning the PID gains enable the poultry house temperature to reach a predetermined set point in the shortest time, with the minimum of overshoot and undershoot than classical PID control.

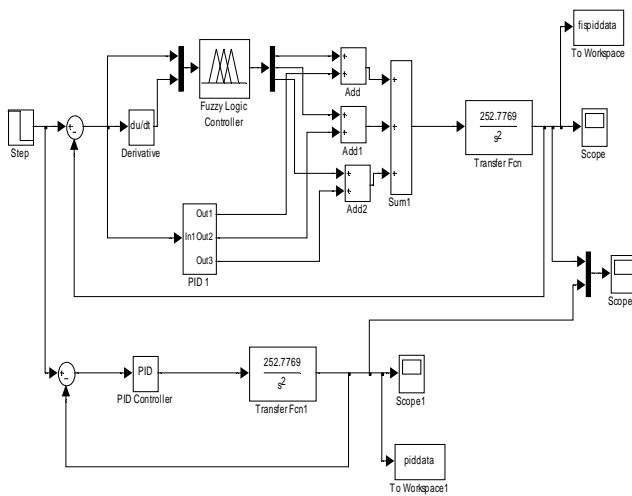
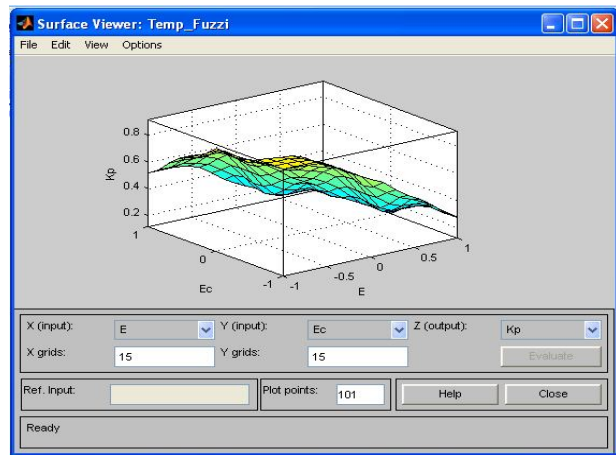


Fig. 4 Simulation model of Fuzzy- PID temperature control system

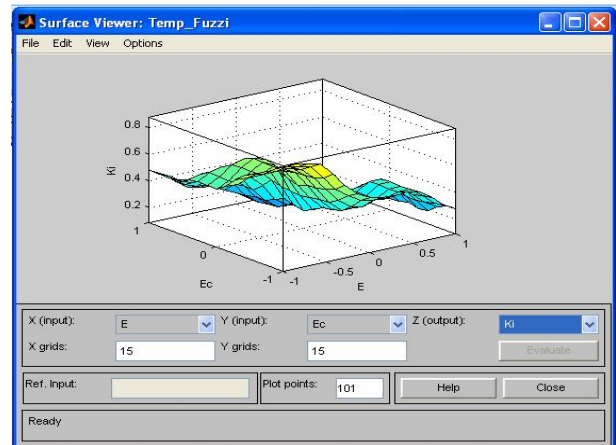
### III. CONCLUSION

This paper emphasizes on the effectiveness of controlling temperature of a poultry house with a Fuzzy-PID controller and its merit over classical PID controller.

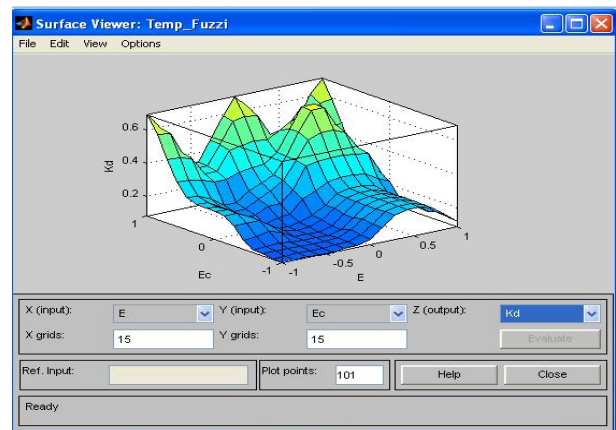
The PID controller and Fuzzy-PID controller for the control of poultry house temperature is designed and is simulated using MATLAB/ SIMULINK package programme. The simulation results show that the Fuzzy-PID controller have better performance in terms of both the steady-state error and the settling time than that of PID controller.



(a)



(b)



(c)

Fig. 5 Surface view of the output  $k_p$ ,  $k_i$  and  $k_d$

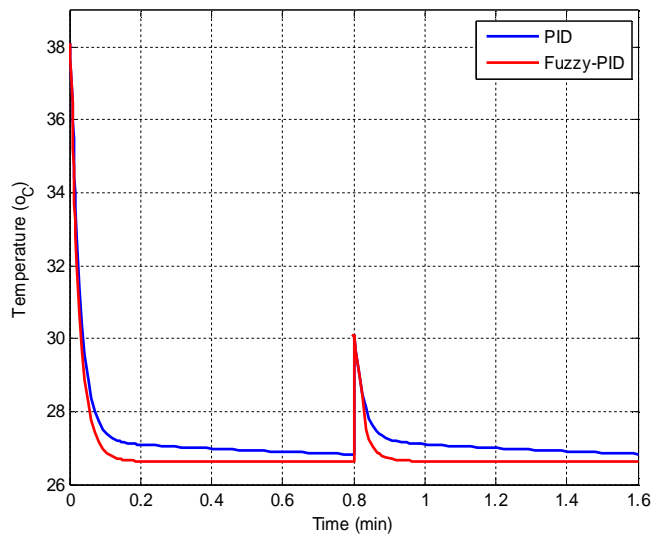


Fig. 5 The comparison of Fuzzy- PID and traditional System simulation

Table 4: Simulation Parameter & Setting

Constant and coefficient	Value
Volume of the room : $V_{room}$	5.2m x 14.1m x 3.1 m
Density of air : $\rho_{air}$	1.2 kg/m <sup>3</sup>
Specific heat capacity air : $C_p$	1.005 kJ/kg°C
Air volume flow rate : CFM	0.1416m <sup>3</sup> /sec
Area of window type1 (LxW): $A_g$	1.2 m x 1.77 m
Surface area of opening for window type1 : $A_{op}$	1m <sup>2</sup>
'u' value for clear 6mm, double glazing glass : $u_g$	2.8 W/m <sup>2</sup> °C
Discharge coefficient for a 'Flat Plate' orifice (hole) opening : $c_d$	0.61
Air velocity leaving the opening (light air) : $v_{air}$	3.4 m/s
Air node correction factor : $F_c$	0.91
Shading factor for double glazing, open horizontal blind and clear 6mm type of glass : $F_s$	0.95
Tabulated cooling load : $q_{sg}$	238 W/m <sup>2</sup>
No. of occupants	25
Sensible heat gain ( $shg$ )	67.413W
Latent heat gain ( $lgh$ )	55.689W
Cooling load factor ( $clf$ )	1
$T_{out}$ and $T_{so}$	38°C
$T_{set}$	26.5°C
$T_{sa}$	22°C

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