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Design of Fuzzy Logic Controller for Humidity Control in Greenhouse

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Abstract:–In the present paper, a fuzzy logic controller was designed to control the humidity inside the greenhouse. This controller can handle two inputs, two outputs and 27 fuzzy rules, also the facility for monitoring the inside and outside humidity was provided. The internal humidity could be set by the user as per the need of the crop in the greenhouse in different seasons required during the lifecycle of the plant. The PWM outputs were generated to control the humidity according to the set point value.

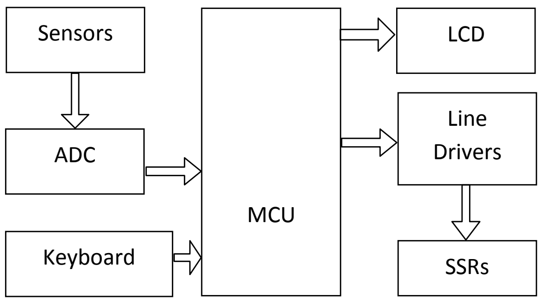
Keywords:–FLC, Fuzzy Inference, Fuzzy Logic, Greenhouse, PWM

I. INTRODUCTION

The greenhouse is a structure that is covered with a material that is transparent to the visible portion of the electromagnetic spectrum, which is utilized in the growth of plant. Humidity control is an important parameter in greenhouse climate control[1] because excess humidity condenses on the leaf surface where it can enhance disease problems also it condenses on the greenhouse structure where it can reduce the light transmission and encourage rust and rot of the structure itself. Greenhouse humidity levels can be reduced by removing the moist around the plants and replacing it with the cooler and drier outside air.

So, with the controlled environment in the greenhouse it is possible to increase the quality and quantity of crop produce per unit land in minimum possible time. Automation in greenhouse is very important for successful management of the greenhouse crops[2][3]. Fuzzy control has been widely applied in industrial controls and domestic electrical equipment[4]. The automatic learning of fuzzy rules is a key technique in fuzzy control. In the present work a controller is designed which will sense the inside and outside humidity of greenhouse, displays it on the screen, allows user to set inside humidity as per the requirement and activate the humidifier or exhausting system accordingly. A fuzzy logic approach is used to decide the output.

II. SYSTEM BLOCK DIAGRAM



The complete system can be implemented using a good combination of hardware and software.

2.1 HARDWARE

The system hardware was designed using Atmel’s 89C52 microcontroller as an MCU, which initialize the system, reads the sensors, displays the values on LCD and take action according to the algorithm. The humidity sensor modules SY-HS230B were used for sensing the inside and outside relative humidity of the greenhouse. This sensor module requires +5 Volt supply. The humidity transmitting range is 10 – 95%RH with accuracy of ± 5%RH. The output voltages for values corresponding value of relative humidity is shown in Table 2.1.

Table 2.1 Relative humidity and corresponding output voltage

Humidity (%RH)	10	20	30	40	50	60	70	80	90	95
Output Voltage (V)	0.70	0.92	1.31	1.70	2.05	2.38	2.71	2.97	3.18	3.30

The outputs of sensor were converted to digital using 8-bit A/D converter IC. A 20x4 LCD display module was used to display the current values of the humidity. This module has four rows of twenty characters in each row. The reason behind selection of this module was to have better interactivity between the user and the hardware; So that the messages could be easily displayed on the screen which could be easily understood by the user. The port 2 pins P2.4 and P2.7 were used for controlling the humidifier and exhausting systems. These lines were connected to the solid-state relays through line driver IC ULN2808. The humidifier and exhausting systems were connected to these solid-state relays so that PWM output can be generated for these systems.

2.2 SOFTWARE

The software was developed using assembly language. The modular programming concept was used so that system can be easily upgraded. The major software modules developed were:

a. Initialization Module
b. Sensor module
c. Keyboard and display module
d. FLC module
e. PWM generation module

After reset, the initialization module loads the variables, stack, and other necessary registers to their default values set by the programmer, initialize the timers and start them. The sensor module sense the inside and outside humidity one by one, converts it to digital and stores them to the corresponding location. The keyboard and display routine allows the user to set the inside humidity also displays the settings and humidity values on the LCD. The FLC module is discussed in section 3. The timer 1 interrupt was used for generation of PWM outputs for the humidifier and exhausting system.

III. FUZZY LOGIC CONTROLLER (FLC)

In the present design, a fuzzy logic controller (FLC) was used for maintaining the relative humidity of the greenhouse to the desired point. The block diagram of fuzzy logic controller is shown in Fig. 3.1

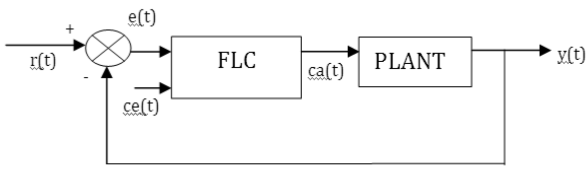


Figure 3.1 block diagram of FLC

A FLC was designed to which two input variables e_{hum} and ce_{hum} were given. The e_{hum} is the error value[5] of relative humidity, which was, computed as:

e_{hum} = humidity set point - current value of humidity

and change in error ce_{hum} was computed as:

ce_{hum} = current e_{hum} – previous e_{hum}

Both of these values are crisp in nature which needs to be converted to fuzzy values. The error value of temp e_{hum} was fuzzified using triangular membership function within the universe of discourse with nine linguistic values, as shown in Fig. 3.2, the linguistic values are NVL (Negative Very Large), NL (Negative Large), NM (Negative Medium), NS (Negative Small), Z (Zero), PS (Positive Small), PM (Positive Medium), PL (Positive Large) and PVL (Positive Very Large). The universe of discourse for error was (-80, +80)% RH.

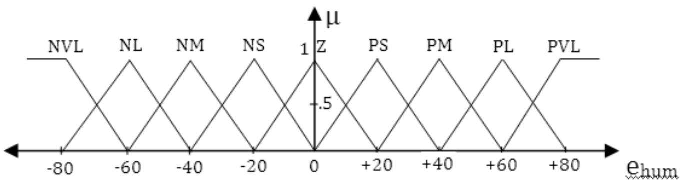


Figure 3.2 Membership function for error

The change in error ce_{hum} was also fuzzified using triangular membership functions with three linguistic values NEG (Negative), Z (Zero) and POS (Positive), as shown in Fig. 3.3.

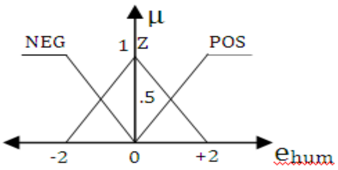


Figure 3.2 Membership function for change in error

The decision making stage consists of fuzzy rules which decides what action to be taken. This is the main block of the fuzzy control and constructed from the expert knowledge and experience. The rule base designed on the basis of knowledge from experts and literature, which consists of 27 rules, as shown in Table 3.1.

Table 3.1 fuzzy logic rule base

ca / e / ce	NVL	NL	NM	NS	Z	PS	PM	PL	PVL
NEG	VH	H	LH	M	VL	M	LH	H	VH
Z	VH	VH	H	LH	VL	LH	H	VH	VH
POS	VL	VL	VL	VL	VL	VL	VL	VL	VL

The selection of either cooling or heating system was based on the error value. If error is positive the heating system will be selected otherwise cooling system would be selected and control action would be applicable to selected system.
The general form of fuzzy logic rule is: IF (condition) AND (condition) THEN (action)

For example, IF e_{hum} is NM AND ce_{hum} is NEG then control action is LH. This process is known as inference. The inference process relates the fuzzy state variables e_{hum} and ce_{hum} to the fuzzy control action ca_{hum}. The control action is also fuzzified using triangular membership function as shown in Fig. 3.4 and has linguistic values VL (Very Low), L (Low), M (Medium), LH (Little High), H (High) and VH (Very High).

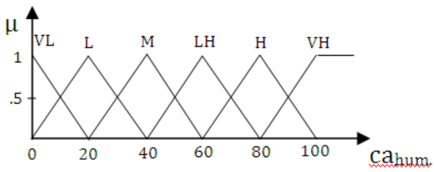


Figure 3.4 membership function for control action

The fuzzy inference engine processes the input data and computes the control outputs using IF-THEN rules. The fuzzy rule-based Mamdani inference[4][6] is shown in Fig. 3.5. These outputs are fuzzy values, which were then converted to crisp value in defuzzification stage.

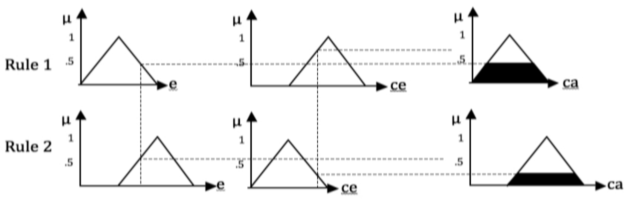


Figure 3.5 Fuzzy inference

Defuzzification:

To convert the fuzzy values obtained by decision-making stage into non-fuzzy or crisp value, the Center Of Gravity (COG), also known as Center Of Area or Centroid[7], method is used. This method has proves to work well with efficient an accurate results[8]. The defuzzified output for the process is calculated by using the equation[9]:

$$y = \frac{\sum_{k=1}^{n} \mu(y_i) \times y_i}{\sum_{k=1}^{n} \mu(y_i)}$$

Where,
y : control action by FLC
k : no. of fuzzy variables
y_i: Peak value of i^{th} clipped fuzzy set
$\mu(y_i)$: Membership value of i^{th} clipped fuzzy set
The defuzzification is shown in Fig. 3.6.

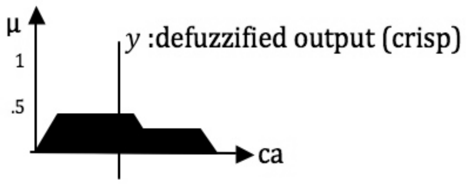


Figure 3.6 defuzzification

The crisp value obtained from defuzzification stage for the corresponding values of e_{hum} and ce_{hum} were stored in the internal ROM as look up table and the values of e_{hum} and ce_{hum} were used to access these crisp values from the look up table. The value read from the look up table was used as percentage on-time duty cycle for PWM output, which was generated using timer 1 ISR. The PWM output was used to control either humidifier or exhausting system depending on the error value e_{hum}. The above procedure was repeated in the program to keep the humidity of greenhouse as per the set point. The PWM waveforms are shown in fig.3.7.

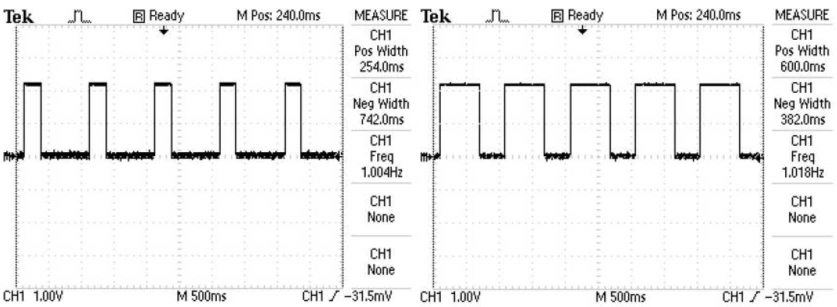


Figure 3.7 PWM waveforms for 25 and 60 % duty cycle

IV. RESULT AND DISCUSSION

The Fuzzy logic controller was implemented for the control of humidity inside the greenhouse using microcontroller 89C52. The software modules were developed and individually tested. The performance of the whole system was then checked. After reset, the system displays the welcome message and the various parameters on the LCD screen. The sensor-routine sense the humidity and display routine and displays the latest data on the screen. The set point facility was checked by making the various set points using keyboard. The controller acts accordingly and FLC routine generates the PWM outputs necessary for maintaining the set humidity in the greenhouse where The FLC shows satisfactory performance in maintaining the humidity of greenhouse.

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