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Evaluation of Intelligent Greenhouse Climate Control System, Based Fuzzy Logic in Relation to Conventional Systems

P. Javadikia, A. Tabatabaeefar, M. Omid, R. Alimardani
Department of Agricultural Machinery Engineering
University of Tehran
Karaj, Iran
{Pjavadikia, atabfar, omid, rmardani}@ut.ac.ir

M. Fathi
Department of Electronic and Informatics
University of Siegen
Siegen, Germany
fathi@informatik.uni-siegen.de

Abstract— **In this paper, at first a model of greenhouse is simulated with thermodynamic equations and then two greenhouse climate controllers (GHCC) are designed using a Fuzzy Logic controller and On/Off controller. The developed Fuzzy Logic Controller (FLC) prototype is based on Mamdani controller and it is built on the MATLAB software, then both of controllers are used with greenhouse model in simulation space of MATLAB software to understand the performance of each controllers and affection on the controlling parameters such as temperature and air humidity of inside the Greenhouse. The results show that the proposed Fuzzy Logic Controller is very user friendly, easy to design, highly adaptable and quick to perform.**

Keywords- fuzzy; on/off; controlling system; greenhouse; simulink

I. INTRODUCTION

The main purpose of a greenhouse is to improve the environmental conditions in which plants are grown. In greenhouses provided with the appropriate equipment these conditions can be further improved by means of climate control [19]. Modern greenhouse and computerized climate control modules have become inseparable nowadays. Computerized climate control is an intrinsic part of present day modern greenhouse [7]. The functions of the computerized climate control can be summarized as follows: (a) It takes care of maintaining a protected environment despite fluctuations of external climate; (b) It acts as a program memory, which can be operated by the growers as a tool to control their crops [19]. The main advantages of using computerized climate control are as follows: (1) Energy conservation [1]; (2) Better productivity of plants [8]; (3) Reduced human intervention [2]. The main environmental factors affecting the greenhouse climate control are as follows: Temperature [5], Relative Humidity [15], of the inside Air; Vapor pressure Deficit [10], Transpiration [14, 13, 3] Sunlight, CO2 Generation [4], Wind speed [15]; and Lighting [5]. Actuators responsible for the climate variations are: Heating System, Cooling System, Mechanical fan, Fog cooling [6, 1, 8, 9], Lighting System [5].

As you know we need simulation of controlling systems to test their applications in real conditions, it helps us to study behavior of them and try to improve their performance and also understand their reflection in rare condition, especially in greenhouse controlling we can find witch system works better and how we can calibrate it.

II. MATERIAL AND METHOD

Fig. 1 depicts the block diagram of the controller embedded in the system model. As can be seen, the controller is operated in five interrelated stages.

1- Set points: This block shows the set points of greenhouse climate that plant can grow up properly.

2- The input variables of greenhouse model: In this stage some variables represent influence on the greenhouse climate such as: inside Temperature, inside air humidity, outside temperature, outside air humidity, radiation.

3- The greenhouse model: This converts the output of actuators and some parameters like temperature, air humidity and outside radiation of greenhouse to the actual temperature and air humidity of greenhouse.

4- The actuator models: These blocks simulate the performances of actuators and receive the output of controllers as the situation of actuators and then give the affections of them in greenhouse.

5- The control stage: In this stage the set points are compared with the measured parameters following the comparison, a dynamic decision is made regarding the situation of the actuators.

In continuation any of five stages will consider that how modeling.

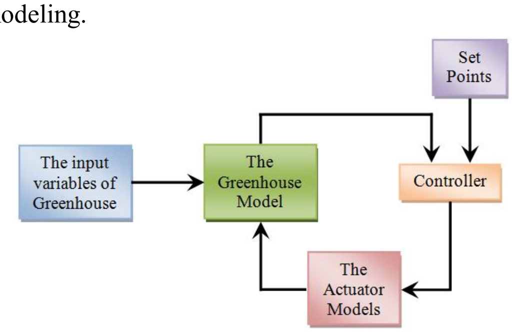

Figure 1. Greenhouse controller block diagram and system model

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A. Set points

At first according to the kind of plant and type of growth extract amount of temperature and air humidity that are necessary for growth, and then with consideration of actual temperature and air humidity of greenhouse, controller determine new situation for actuators to get minimum error in temperature and air humidity from set points.

B. The input variables of greenhouse model

In addition to the amount of actuator outputs to be added to the greenhouse model, three effective factors as: outside temperature, outside air humidity, light intensity influence on the greenhouse climate. The input variables were defined as follows:

a) Outside temperature: This variable should be defined as a continuous signal (normally as a sine wave which simulated the day and night temperature changes), but my show sharp changes in special places like deserts, and so on therefore:

- A sine wave with amplitude of 5 ºC;
- A frequency of 0.2618 rad/h. This frequency is measured according to a time period of 24 h: 0.2168 rad/h = 2π/T=2π/24.
- a constant bias(offset) of 30 ºC;

This stimulus generates a wave which at its maximum can reach 35°C (midday) and at its minimum can reach +25°C (midnight). In this way, the temperature on any given day can be simulated by changing the bias that is attached to the variable. This diversion is obtained by uniform number generation. (Light red graph in Fig. 2.)

b) The Air humidity variable

- a sine wave with amplitude of 10%;
- bias of 60% (constant);
- a frequency of 0.2618 rad/h.(blow graph in Fig. 2.)

c) Light intensity: We can simulate radiation changes like before variables but my compiled software in MATLAB has ability to model the radiation with using the geographical equations that is explained in previous article[16]. (Yellow graph in Fig. 2).

C. The greenhouse model:

The first step for an advanced control design is the development of a dynamic model. Model quality is a fundamental aspect to achieve adequate control performances. It is possible to divide models into two groups [19; 12]:

1) First principles models: Those that provide physical phenomena by means of differential equations (usually by state space models). In this type of models, parameters have a physical interpretation.

2) Black box models: Those that try to approximate the behavior without a priori information, for instance, polynomial fitting, neural networks, Fuzzy sets, etc.

It is difficult to select a priori the most useful type of model. Both can have a very good quality. First ones are more understandable but their development is difficult and very expensive. The second group has no physical meaning but is easier to obtain.

However, because building and occupant thermal interactions are coupled with time constants on the order of many minutes, not seconds, their dynamic interaction may be safely ignored for dynamic controller design. Chao and Gates [11] reviewed recent models for greenhouses, from which we take the following dynamic equations for interior air temperature. Note that conversion of sensible heat to latent heat is accounted for by using a “net” sensible heat term in each equation. A greenhouse dynamic equation is:

$$\rho C_p V \, {}^{\partial T}\!/\!{}_{\partial t} = (q_h + aSA_f) - \rho C_p V(T - T_o) - UA_s(T - T_o) \quad (1)$$

Variables in these equations are defined as:
A_f = floor area (m^2)
A_s = surface area (m^2)
a = building net solar heating efficiency (set to 0.28 in these simulations)
C_p = specific heat of air [J (kg °C)$^{-1}$]
q_h = heater output (W)
ρ= air density (kg m^{-3})
S = solar irradiance (W m^{-2})
T = interior air temperature (°C)
T_{out} = outside air temperature (°C)
U = overall building thermal conductance (W m^{-2} °C^{-1})
V = building volume (m^3)
V. = volumetric ventilation rate (m^3 s^{-1})

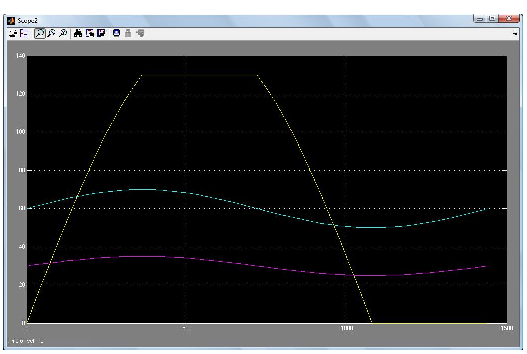

Figure 2. The input variables of greenhouse model-graphical presentation.

D. The actuator models

These models get the outputs of controller as inputs that are between [0,100] at fuzzy controller and 0 or 100 at on/off controller and then after calculating give special amount that is output of every actuators.

E. The control stage

The control stage interfaces the inside temperature and air humidity of greenhouse with the input variables. This stage is intended to keep the actual temperature and air humidity as close as possible to the desired set points. Its output is the actuators value, which represents the percentage of power that actuators should be worked continuously in order to maintain a minimal deviation. The block diagram of the fuzzy controller is shown in Fig. 3.

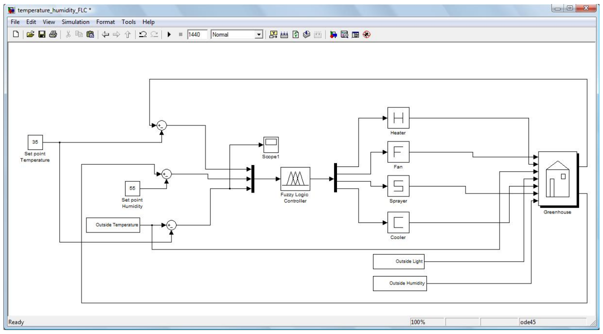

Figure 3. Diagram of the fuzzy controller system with the greenhouse model.

As can be seen from this figure, the controller has three input signals (the difference between the desired and the actual inside temperature, air humidity and outside temperature values) and four output parameters (heater, fan, cooler and sprayer). The input values are defined in the range [−100, 100] and the output values are defined in the range [0, 100]. By doing so, the controller can specify the actuator operations in the desired range.

There are five membership functions in any inputs. These membership functions are presented in Fig. 4.

The block diagram of the on/off controller with hysterics and without it is shown in Fig.5. In simple on/off controller the actuators is working when desired set points are more than actual amounts but in on/off controller that equipped to hysterics the actuators is working when desired set points are more than actual amounts at least of the hysterics value.

III. Simulation Results (Behavior of Output)

Fig. 6-11 shows the graphical representation of the simulation results. The legend is as follows:

Light red signal — desired set points;

Yellow signal — actual temperature or humidity;

In Fig. 8 and Fig. 11 from up to down are about Heater, Cooler, Fan, Sprayer outputs in on/off and fuzzy controller system respectively;

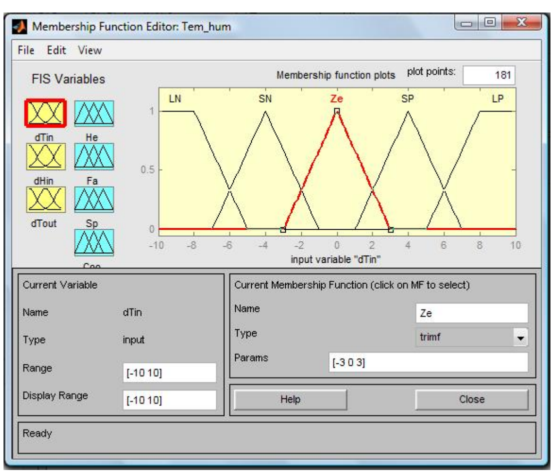

Figure 4. Fuzzy variable “the difference between the desired and actual values”.

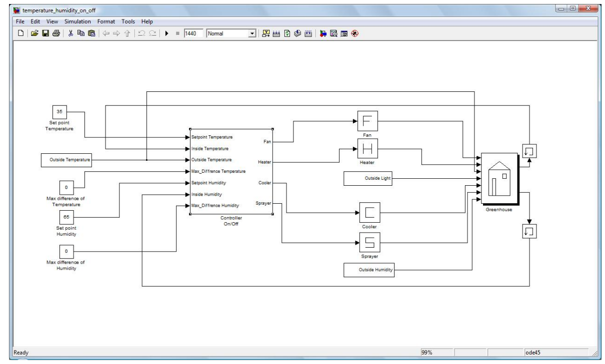

Figure 5. Diagram of the on/off controller system with hysterics and without it.

There are several very important facts that can be extracted from figures 6-11:

- In on/off controller system, actual values tracks desired one but there are continuous oscillations around the desired values in actual values in other words system isn't stable completely.
- The actual values tracks the desired one without any oscillation in fuzzy controller system
- In fuzzy controller the difference between values (the "error") is reasonable, and it is quite steady (around 2-3%). This shows that the climate controller is stable.

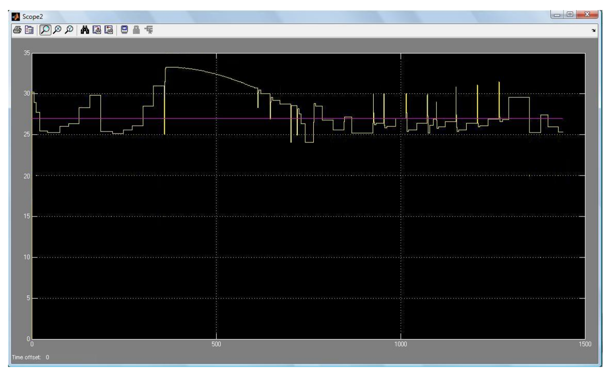

Figure 6. Simulation results of on/off controller system for temperature

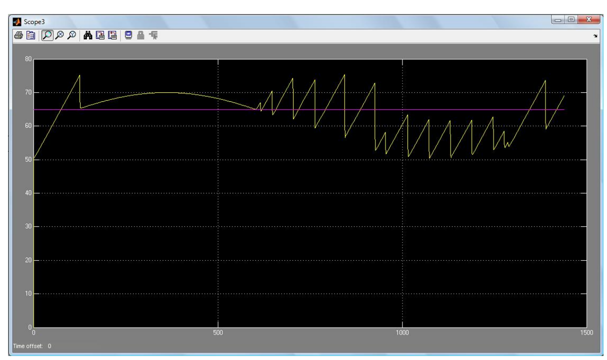

Figure 7.Simulation results of on/off controller system for humidity

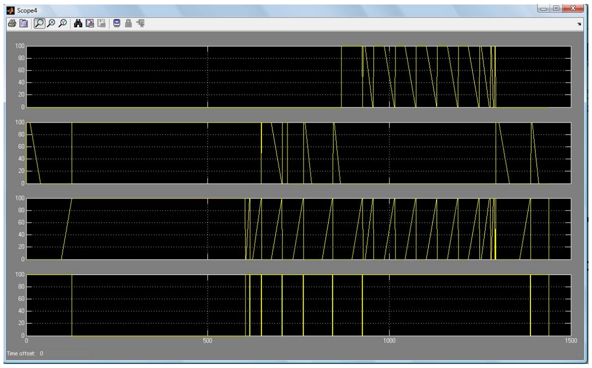

Figure 8. Simulation results of actuators in on/off controller system

- In fuzzy controller system the on/off of actuators and consumption of energy is less than on/off controller system and so is prevented of wastage of energy and depreciation of actuators (Fig. 8 and Fig. 11).
- Each of two controller system, the source-generation model allows the user a wide variety of climate combinations; therefore, the controller can operate in any circumstances.
- The main target — to design a cheap and reliable greenhouse climate controller — has been achieved in fuzzy controller system.

IV. CONCLUSIONS

This paper has compared two systems equipped to on/off and fuzzy controller with each other. First, it explained the general architecture and its components. Then some examples showed that the system operates within the proper range, and is stable. Consequently fuzzy controller system had more ability as compared

with another system. It is important to note that such system can save a lot of energy, and is very cheap to implement. The fuzzy membership functions are simple (as shown in Fig. 4), therefore making the system attractive to use by all types of agriculturists.

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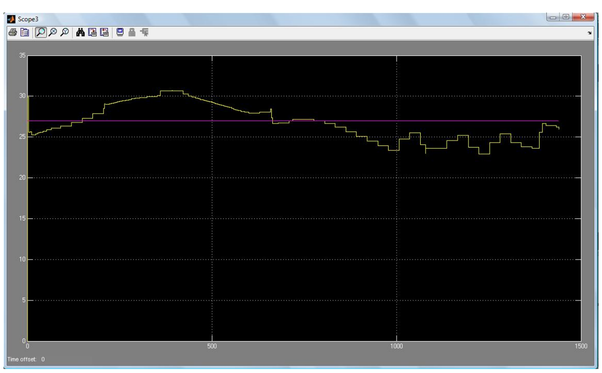

Figure 9. Simulation results of fuzzy controller system for temperature

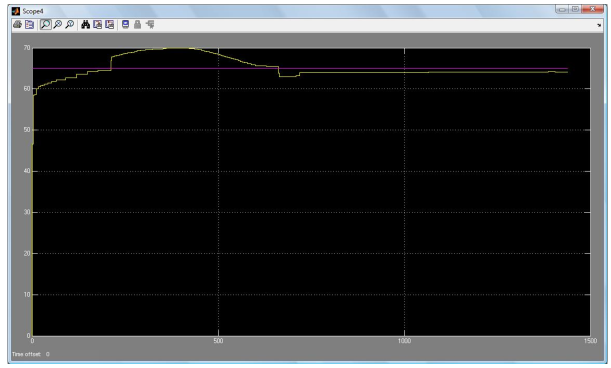

Figure 10. Simulation results of fuzzy controller system for humidity

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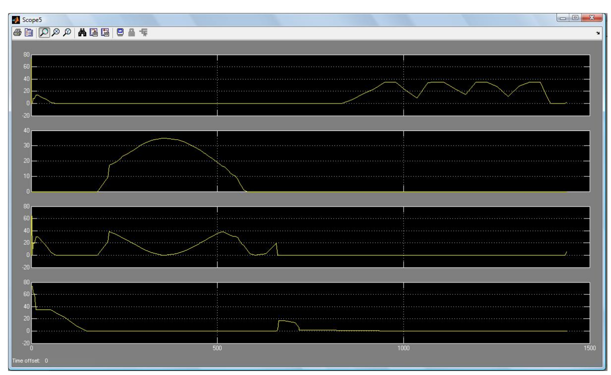

Figure 11. Simulation results of actuators in fuzzy controller system

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