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Microclimate Control in a Production Shop Using a Fuzzy Controller

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Abstract

The microclimate in a production area has a great influence on the personnel health and performance at enterprises. The microclimate of production areas is controlled, for example, using ventilation units. Air handling unit control systems implement various control algorithms. One of them is the use of fuzzy regulation. Fuzzy control is widely used in control systems when traditional quantitative methods are not applicable. Fuzzy controllers work well in control systems for complex nonlinear systems, as well as systems with nonlinear external disturbances. Recently, fuzzy controllers have become widespread in process control systems. Such regulators allow using the experience of process operators. This paper considers the development and practical implementation of a fuzzy controller based on an industrial controller for controlling the microclimate in the production area. The following input variables were selected: the temperature in the production area, the ambient temperature, the air temperature at the exhaust unit, the supply air temperature, and the room humidity. The output variables are the opening levels of the inlet and outlet valves. For each of the variables, ranges of variation and membership functions have been determined, and a rule base has been developed. To implement the control algorithm, the industrial controller software has been developed. The results of the algorithm implemented with the use of an industrial controller coincide with the results obtained in the sciFLT simulation environment of the SciLab package.

Keywords: intelligent microclimate control, fuzzy controller.

I. INTRODUCTION

Human performance and health status largely depend on the working conditions in the workplace. These include lighting, noise, microclimate, etc. Various control systems for environmental factors inside production areas are used to ensure the necessary working conditions at workplaces.

According to sanitary norms and rules, the working environment is understood as a combination of temperature, relative humidity, speed of movement and dustiness of the air. It is the combination of these parameters that determines the comfort for a person in the room. The air temperature at the workplace is one of the main parameters characterizing the state of the microclimate. Air humidity is also important for comfort. The concepts of absolute and relative humidity are most often used to describe the air humidity.

Ventilation units are used to control the microclimate of production areas. In general, they contain extract and supply fans, recuperator, heat exchanger, filters, actuator operated valves, etc.

Air handling units can be controlled using traditional PI and PID controllers, as well as those based on fuzzy logic. Recently, fuzzy controllers are often used in automated control systems [1-5].

The system for ensuring a favourable microclimate is difficult to describe using traditional equations, since it is a non-linear system with dynamically changing parameters. In such cases, it is advisable to use the knowledge and experience of subject matter experts to control the system in order to describe the levels of thermal comfort without accurate parameter estimates. The use of fuzzy control is especially effective in the case when the value of the output parameter depends on a set of input parameters.

This paper discusses the use of a fuzzy controller based on an industrial controller to control the microclimate of a production area.

II. METHODS

In the modern theory of automated control, intelligent technologies are becoming increasingly common. They are used in a variety of tasks: from equipment diagnostics up to control of unmanned vehicles [6-9]. Modern production facilities, as a rule, are nonlinear and cannot always be described strictly mathematically. Fuzzy logic elements are used to control such objects. Fuzzy logic-based control turns out to be especially effective in cases when the control object is a complex dynamic system with changing parameters, for which there is not enough a priori (initial) information to model its operation, or traditional quantitative methods are not applicable [10-12].

Fuzzy logic control uses sentences in the form of rules. A regulator based on fuzzy logic is built on the basis of the user's knowledge and experience and can be developed without using specific knowledge about the control object. Fuzzy controllers have proven themselves well in controlling complex nonlinear systems, as well as systems with nonlinear external disturbances. The use of fuzzy control is most effective in cases where it is difficult to obtain a model of a technological process in an explicit form or the resulting model in an analytical form is difficult for use in real-time systems [13].

Usually a fuzzy controller has the structure shown in Figure 1. The figure shows: 1 - fuzzification unit; 2 - fuzzy inference unit; 3 - defuzzification unit; 4 - rule base unit; 5 - control object [15].

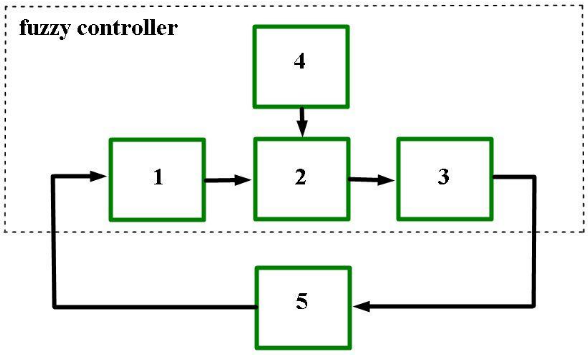

Figure 1. Block diagram of the regulator

A fuzzy regulator consists of the following main units:

- Fuzzification unit, which converts the clear values of the input variables into fuzzy values. The range of variation in value is divided into subsets. Membership functions for a variable, for example, of a triangular shape, are created in the obtained subsets.
- The rule base unit is a set of intuitive linguistic rules that display the relationship between the inputs and outputs of the control object. The rules are as follows: If - then.
- The fuzzy inference unit implements an algorithm for obtaining membership functions of control actions. A set of fuzzy rules and fuzzy variables are collectively used to implement fuzzy inference.
- The defuzzification unit (inverse to the fuzzification unit) transforms the membership function obtained at the output of the fuzzy inference unit into a clear physical value of the actuator control action. The purpose of defuzzification is to obtain the values of the output variables using logical conclusions.

Control when using a fuzzy controller is implemented as follows:

1) Status data from the control object (5) is fed to the input of the fuzzification unit (1). Here the received information is converted into fuzzy data.
2) Membership functions of control actions are formed by the fuzzy inference unit (2), based on fuzzy input data, in accordance with the rule base (4).
3) In the defuzzification unit (3), the membership functions obtained at the output of the fuzzy inference unit (2) are converted into a clear physical value of the control action.
4) The control object (5) changes its state in accordance with the received control actions.

Fuzzy inference systems can use various algorithms. One of the most commonly used in practice is the Mamdani algorithm. This algorithm describes the following sequentially executed stages: formation of the rule base, fuzzification, aggregation of subconditions, activation of subconclusions, accumulation of conclusions, defuzzification.

III. RESULTS AND DISCUSSION

Consider a control system for an air handling unit based on a fuzzy controller. Simulation was carried out in sciFLT environment. In this work, the Mamdani algorithm was used for fuzzy inference. The centroid method was used for defuzzification.

The input linguistic variables are:

1) Room temperature containing two terms (positive deviation, negative deviation);
2) Ambient temperature containing three terms (low, normal, high);
3) Air temperature at the exhaust unit, containing three terms (low, normal, high);
4) Supply air temperature containing three terms (low, normal, high);
5) Indoor humidity containing three terms (positive deviation, negative deviation).

The output linguistic variables are:

1) The level value for the supply valve opening, containing three terms (low, optimal, high);
2) The level value for the exhaust valve opening, containing three terms (low, optimal, high).

Let us consider a fuzzy inference using the example of controlling the supply valve and the exhaust valve of an air handling unit.

The process of regulating temperature and humidity in a room can be represented in the form of heuristic rules. 108 rules were developed in the work [14]:

1) **If** the indoor temperature has a positive deviation **and** the outdoor temperature is low **and** the supply air temperature is low **and** the exhaust air temperature is low **and** the humidity has a positive deviation, **then** the supply valve opens at low level **and** the exhaust valve opens at low level.

25) **If** the indoor temperature has a positive deviation **and** the outdoor temperature is normal **and** the supply air temperature is normal **and** the exhaust air temperature is low **and** the humidity has a positive deviation, **then** the supply valve opens at high level **and** the exhaust valve opens at normal level.

50) **If** the indoor temperature has a positive deviation **and** the outdoor temperature is high **and** the supply air temperature is high **and** the exhaust air temperature is low **and** the humidity has a negative deviation, **then** the supply valve opens at high level **and** the exhaust valve opens at normal level.

75) **If** the indoor temperature is negative **and** the outdoor temperature is normal **and** the supply air temperature is low **and** the exhaust air temperature is normal and the humidity has a positive deviation, **then** the supply valve opens at normal level **and** the exhaust valve opens at normal level.

108) **If** the indoor temperature is negative **and** the outdoor temperature is high **and** the supply air temperature is high **and** the exhaust air temperature is high **and** the humidity has a negative deviation, **then** the supply valve opens at high level **and** the exhaust valve opens at low level.

The representation of the rules in the sciFLT environment is shown in Figure 2.

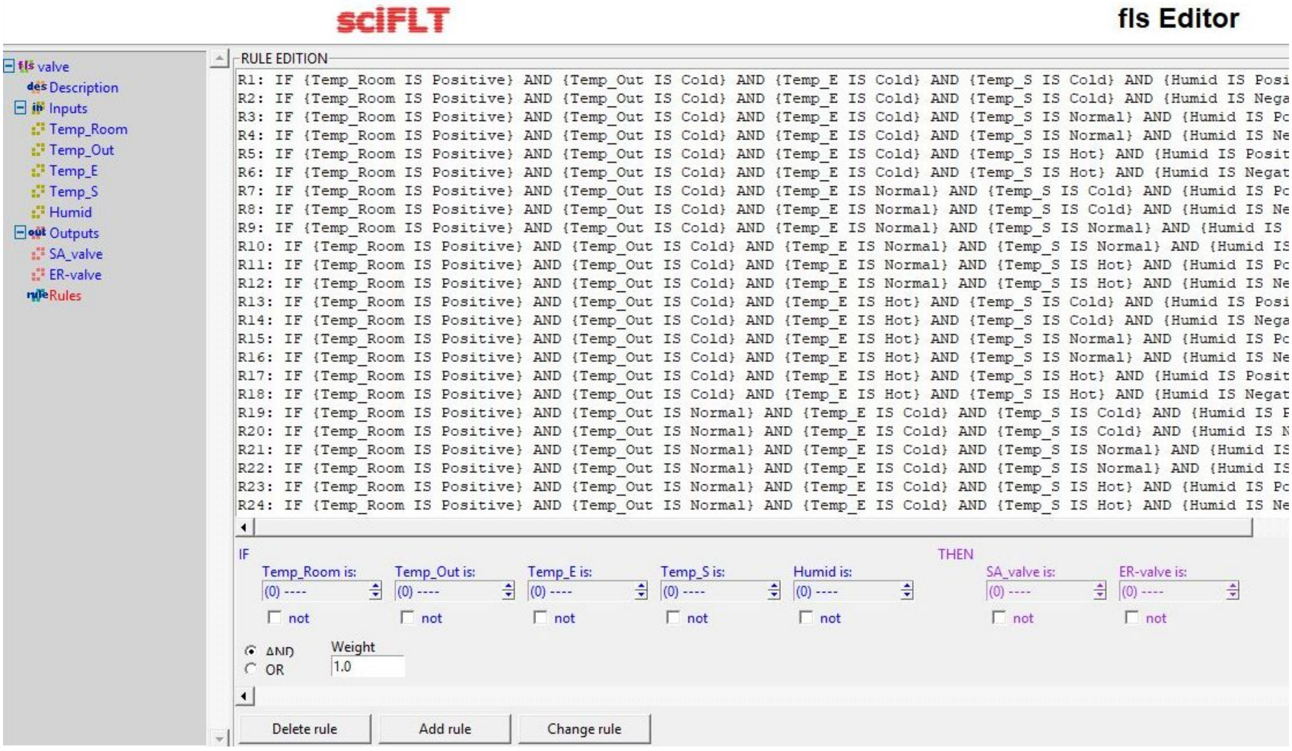

Figure 2. Representation of rules in sciFLT environment

The fuzzy controller was implemented on the basis of a programmable logic controller. The development of an automated control system based on a fuzzy regulator is reduced to solving the following tasks:

1) Analysis of the control object and the choice of input and output linguistic variables;

2) Determination for each of the linguistic variables for the approximating fuzzy set;

3) Development of the rule base.

The program operation algorithm using the fuzzy logic rule base for the Siemens industrial controller is implemented in the STL programming language. Some fragments of the program are shown in Figures 3-5.

```
IF #temp<=0 THEN
    #Mu := 0;
END_IF;
IF #temp>0 AND #temp<10 THEN
        #Mu := #temp / 10;
    END_IF;
    IF #temp >= 10 THEN
        #Mu := 1;
    END_IF;
```

Figure 3. Calculation of the grade of membership according to the term "Positive deviation of room temperature"

```
IF #Temp2 <= 5 THEN
    #Mu := 1;
END_IF;
IF #Temp2 > 5 AND #Temp2 < 15 THEN
    #Mu := (15-#Temp2) / 10;
END_IF;
IF #Temp2 >= 15 THEN
    #Mu := 0;
END_IF;
```

Figure 4. Calculation of the grade of membership according to the term "Low ambient temperature"

```
IF #temp3 <= 10 THEN
    #Mu := 1;
END_IF;
IF #temp3 > 10 AND #temp3 < 15 THEN
    #Mu := (15 - #temp3) / 5;
END_IF;
IF #temp3 >= 15 THEN
    #Mu := 0;
END_IF;
```

Figure 5. Calculation of the grade of membership according to the term "Low exhaust air temperature"

To check the results of the algorithms, the following input data were used: the room temperature has a positive deviation of 2 °C, the outdoor temperature is 25 °C, the air temperature at the hood is 18 °C, the supply air temperature is 23 °C, and the humidity deviation in the room is 5%.

The controller operation simulation showed that under these conditions the supply valve should open by 50%, and the exhaust valve - by 30%. The same data was obtained when tested in the sciFLT simulation environment.

IV. SUMMARY

The paper proposes to control the microclimate of the production area on the basis of a fuzzy controller. The regulation is implemented using an industrial controller. Based on the simulation of the controller's operation, control actions similar to the results obtained in the sciFLT simulation environment were obtained.

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