Fuzzy Controller for Adjust the Indoor Temperature and Preservation the Buildings

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Abstract: - Thermal comfort in buildings, efficient use of energy for heating and preservation of the buildings against degradation are obtained by equipping buildings with adequate installations. Indoor temperature, relative humidity and dew point temperature from buildings can influence the degradation of the buildings and the health of the occupants. This article proposes the use of a fuzzy controller for automatic temperature control in buildings which are not equipped with facilities humidification / dehumidification. The fuzzy controller can avoid the condensation of water vapour from the air on the cold surfaces inside buildings. In case of increasing the air relative humidity, the buildings will be protected against mould formation and metal corrosion, but the disadvantage is that it reduces the thermal comfort in buildings.

Key-Words: - fuzzy controller, fuzzy automatic system, model of system, preservation of building, thermal comfort, heating system, dew point temperature

1 Problem Formulation

Correctly control of the indoor temperature in buildings ensures the thermal comfort of the occupants and reduces the energy to heat the buildings. Several methods are known for automatic control of the heating systems in buildings that use thermal agent and all methods adjust the amount of heat introduced into the building to be equal to the amount of heat lost through the building envelope. At the thermal balance, the indoor temperature in the building is kept constant at the set point.

The presence of people in the building, the activities taking place there and the external environment affect indoor air humidity. The combinations for values of the indoor temperature and the relative humidity (RH) of indoor air, cause changes in the values of dew point (DP) and thus may occur condensation of water vapor from the air on the cold surfaces within the building.

At a constant indoor temperature (e.g. 20^0C), the values too small or too large for RH may expose the building at four type of decay: natural aging, metal corrosion, mechanical damage and mold risk [1].

Experimental studies show that RH values must be preserved in buildings, both in summer and winter, between RH = 30% ÷ 60% [2 - 5]. In these conditions the buildings are protected against degradations which have been reported before. More, it is recommended RH = 45% ÷ 55% in order not to endanger the health of building occupants [6]. The value RH = 50% is the optimum value of the relative humidity which must be maintained in buildings by means of special installations for this purpose [3, 5].

The condensation of water vapors from the air on a cool surface inside the building takes place only if the surface temperature is lower than the DP. The fall in DP value eliminates the danger of condensation. The fall in value of the indoor temperature in the building causes the decrease DP value [1. 2].

The buildings that are not equipped with humidification / dehumidification facilities can be partially protected against degradation in case of increase the RH value, by lowering the indoor temperature value by means of appropriate automated heating system dedicated for this purpose. This article provides a solution in this case by using a specialized fuzzy controller and a sensor that measures air humidity. The automatic system with fuzzy controller is modeled using Simulink from Matlab.

Simulink models are used for temperature control systems in buildings that has been previously performed by the authors [8,9,10,11].

2 Fuzzy Controller for the Temperature Control

The fuzzy controller (FuzzyTemp) calculates the value of thermal agent temperature (ThAgTemp) depending on the indoor temperature (IndoorTemp) and relative humidity in the building (RH). The fuzzy controller output is connected to the setpoint of the nonlinear regulator that controls the thermal agent temperature in the heating system of the building.

IndoorTemp may vary between 10^0C and 30^0C. The occupants of the building appreciate the values of this temperature as "Very Cold", "Cold", "Comfort", "Warm" and "Hot", as shown in Figure 1.

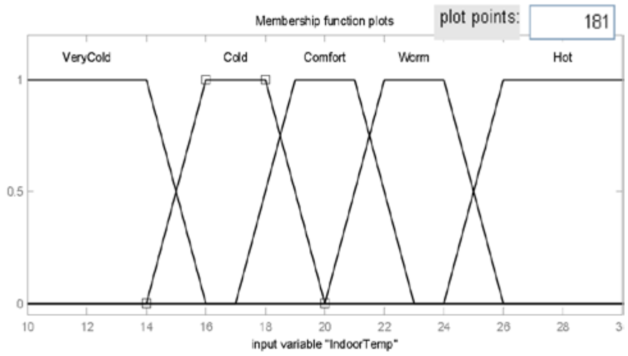

Fig. 1 Membership functions for „IndoorTemp"

RH can vary between 10% and 90%. For occupants of the building and for the building itself is estimated RH by "VeryDry", "Dry", "Health", "Humid" and "VeryHumid", as shown in Figure 2.

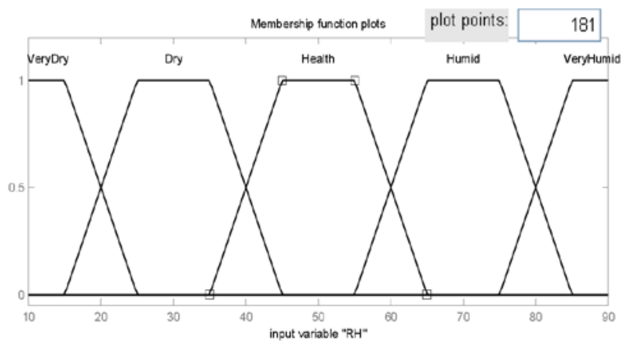

Fig. 2 Membership functions for „RH"

The output "ThAgTemp" from the fuzzy controller is the reference for the temperature of the thermal agent. This temperature can range from 30^0C (minimum allowable temperature at which a cast iron boiler can operate) to 80^0C (the temperature at which the boiler works with a very good yield).

Figure 3 shows how the values of ThAgTemp are assigned for heating the building: "StrongCooling" "EasyCooling" "HoldTemp" "EasyHeating" and "StrongHeating".

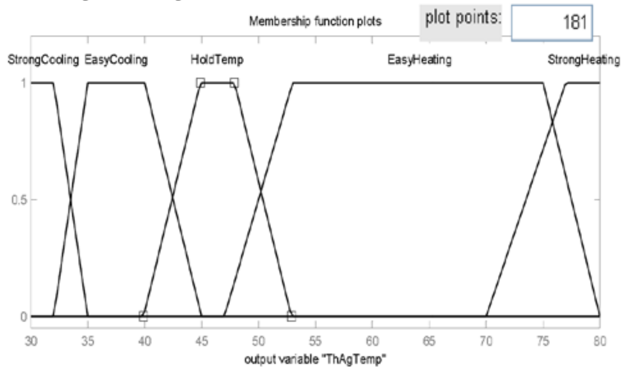

Fig. 3 Membership functions for „ThAgTemp"

It can be seen that it was adopted "the trapezoidal membership function".

They were established 25 rules that define the behavior of the automatic system with fuzzy controller. These if-then rule statements are used to formulate the conditional statements that comprise fuzzy logic used in the automatic system.

The Rule Viewer, from Matlab, is used to view the fuzzy inference diagram (fig. 4).

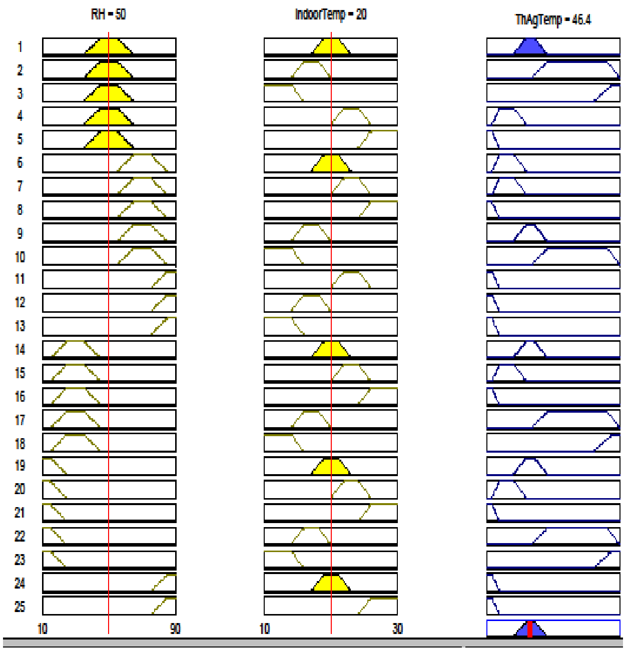

Fig. 4 Fuzzy inference diagram

The Surface Viewer, from Matlab, is used to view the dependency of the output on the two inputs of the controller. The surface map for the fuzzy system it is shown in figure 5.

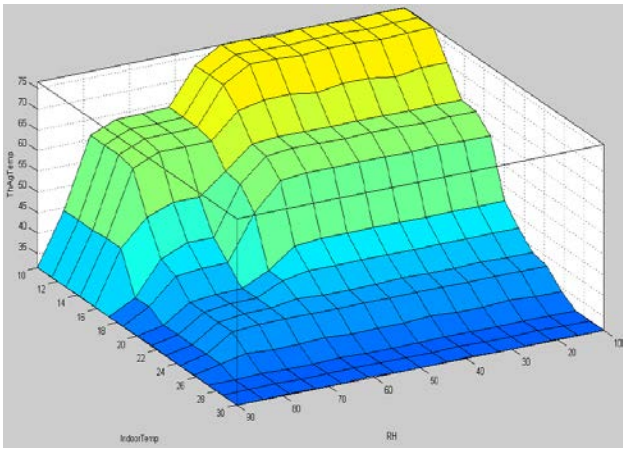

Fig. 5 Surface map for the fuzzy system

3 Validation of the Model for the Fuzzy Automatic System

We start from the classic automatic system used to adjust the indoor temperature in non-residential buildings. This system operates using the principle adjusting by anticipation, namely temperature of the thermal agent changes depending on the outdoor temperature (dominant disturbance). The system uses a nonlinear regulator, a three-way control valve and a special block called Heating Curve) [8,9,10]. This block sets the reference for the nonlinear regulator depending on outdoor temperature. The system does not take into account the values for relative humidity. The system is shown in Figure 6, the lower part of the figure.

The automatic system with fuzzy controller (Figure 6, top) keeps all components of the classic automatic system, except Heating Curve block. The fuzzy controller is connected in cascade with the nonlinear regulator and supply it the setpoint for thermal agent.

The automatic system with fuzzy controller is validated by comparison with the classic automatic system using the same building. For the system with fuzzy controller, the relative humidity in the building is considered RH = 50% = ct.

Figure 7 illustrates the simulation results of the two automatic systems: thermal agent temperature and indoor temperature. The red graphs are for the classic system and the blue graphs are for the fuzzy system. Simulation is for 180000 seconds (50 hours). The time range for simulation was chosen to be longer than the transient regime of buildings with considerable thermal inertia.

The outside temperature varies sinusoidal (24 hours period), between -8°C (night) and + 4^0C (day).

After transient regime that appears at the beginning of simulation of the automatic systems are noted the following:

- the maximum thermal agent temperature variation is lower for fuzzy system, that leads to a reduced consumption of thermal energy for heating the building;

- the maximum variation of indoor temperature around the imposed value 20^0C is lower for the fuzzy system, that leads to a better thermal comfort in the building.

Based on the foregoing, it can be considered that the automatic fuzzy model is validated.

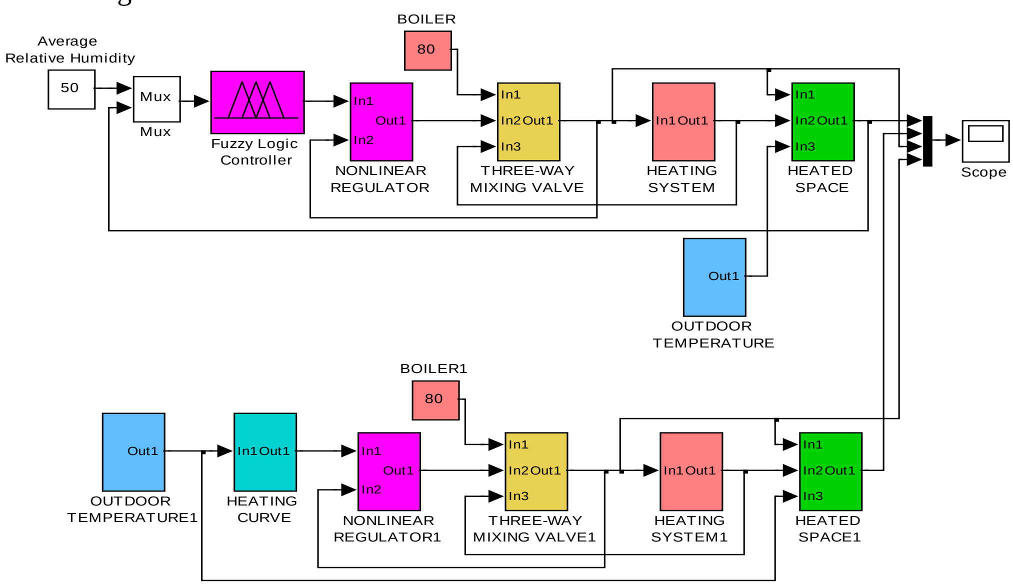

Fig. 6 Models for classic and fuzzy automatic systems

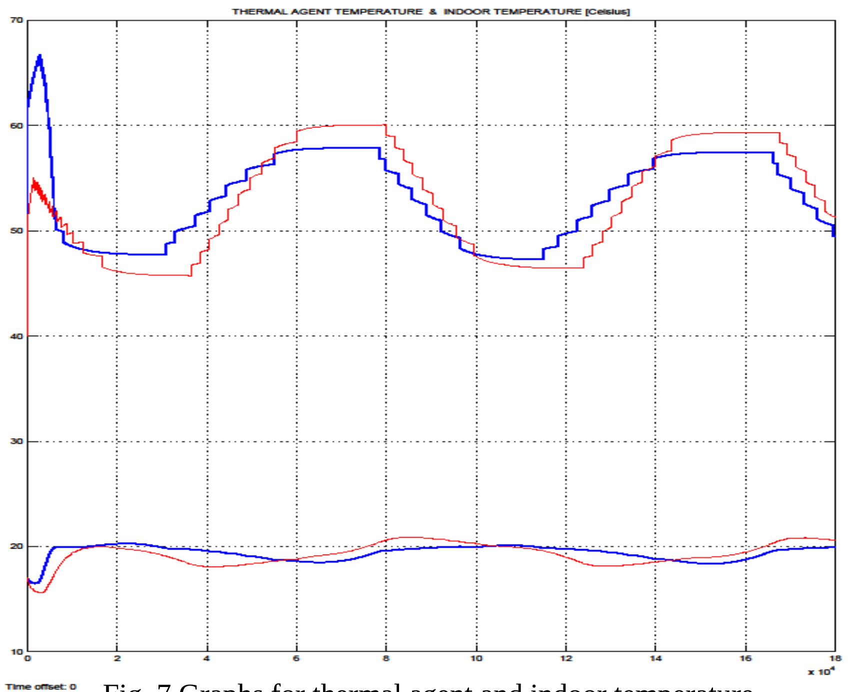

Fig. 7 Graphs for thermal agent and indoor temperature

4 Analysis of the Fuzzy Automatic System that Preserves the Building Against Degradation

The fuzzy automatic system that preserves the building against degradation is presented in figure 8.

RELATIVE HUMIDITY block was designed to produce a linear variation for RH increasing from 10% to 90%, within the timeframe 180000 seconds (50 hours) selected for simulation. The usual value RH = 50% is exceeded with ± 40%.

The building is not equipped with a RH control system. Building protection against mold risk and metal corrosion at high levels of RH is made by decreasing the indoor temperature (fig. 9), that involves decreasing the value of DP.

It may be noted the protective effect of the building assured by the fuzzy automatic system after approx. 90000 seconds, when RH > 55%. The indoor temperature decreases to approx. 13^0C with increasing RH from 55% to 90%.

The mold risk disappears but the thermal comfort in the building is reduced.

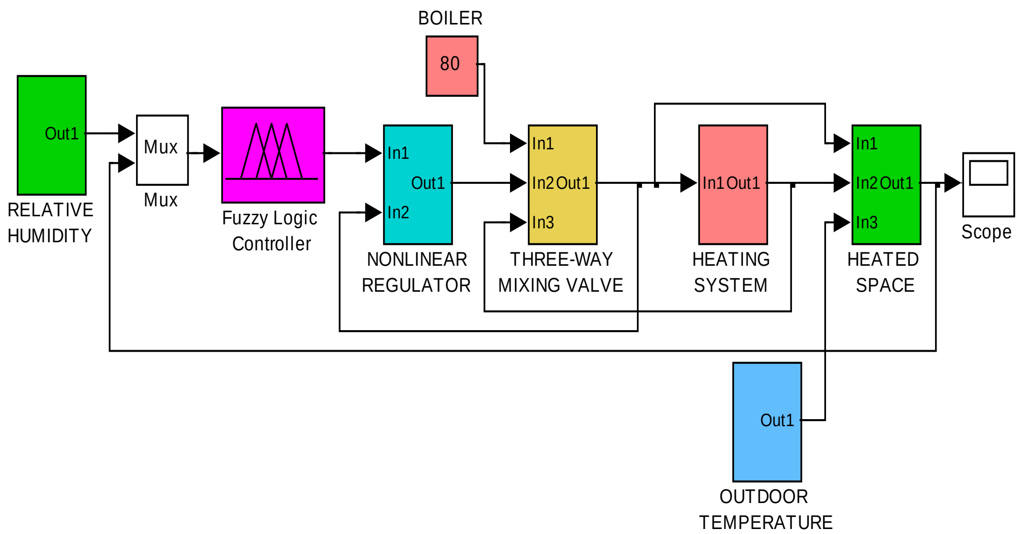

Fig. 8 Model for fuzzy automatic system that preserves the building

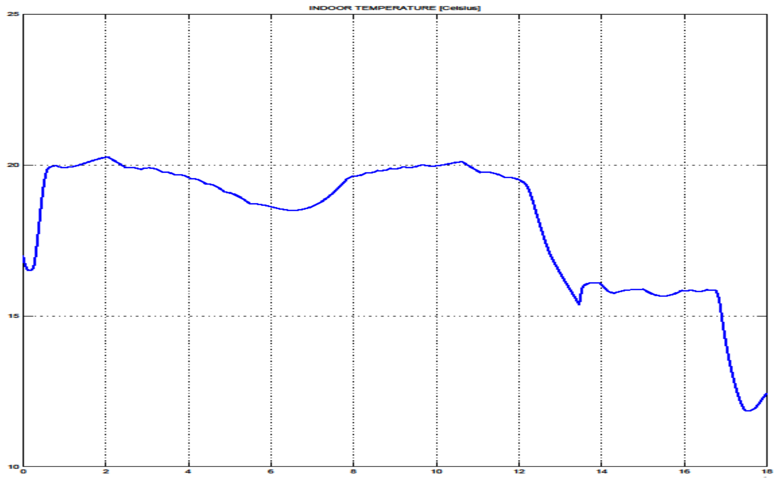

Fig. 9 Building preservation by decreasing the indoor temperature

5 Conclusion

Thermal comfort and buildings preservation can be obtained simultaneously only by equipping the buildings with advanced systems for heating, ventilation, air conditioning, humidification / dehumidification.

The proposed solution solves only the protection of the buildings against mold formation and metal corrosion and has the disadvantage that reduces thermal comfort in buildings. That is why the fuzzy automatic system can be used only where the conservation of buildings is more important than thermal comfort (libraries, museums, archives, etc.)

Fuzzy system eliminates condensation of water vapor in the air on cold surfaces inside buildings by controlling the value of DP.

For the buildings where is maintained RH = 45% ÷ 55%, the fuzzy system is preferred to be used instead of the traditional heating automatic system, because the indoor temperature is adjusted more precisely and with less consumption of heat.

Better performances for temperature control in buildings can be obtained if in the proposed fuzzy system, the nonlinear regulator is replaced with a linear one.

References:

[1] http://www.dpcalc.org/, Dew Point Calculator, Rochester Institute of Technology, New York

[2] Gabriel Teodoriu, Ion Şerbănoiu, Decision analysis to evaluate thermal comfort in residential buildings, *Romanian Civil Engineering Journal*, Volume 4 (2013), No 3

[3] ASHRAE STANDARD 55:2004, *Thermal Environmental Conditions for Human Occupancy*, 2004

[4] EN ISO 7730:2005 – *Ergonomics of the thermal environment*, 3rd edition, 2005

[5] L. Ekberg, Revised Swedish Guidelines for the Specification of Indoor Climate Requirements released by SWEDVAC, *Proceedings of Clima 2007 WellBeing Indoors*, 2007

[6] http://bioclima.ro, Romanian Association of Balneology, National Conference of Balneology, 12-14 May 2011 - Neptun, Romania

[7] http://www.isover.ro/, ISOVER Saint-Gobain

[8] Popescu, D., 2016, Modeling and Simulation of the Systems for Temperature Control in a Building, In Review 13989-40961-1-SM.DOC 2016-01-18, Elektronika ir Elektrotechnika, Print ISSN: 1392-1215

[9] Popescu, D., Borza, I., Modelling and Simulation of the Temperature Control System in the Heating Installations from Non-residential Buildings, *Proceedings of SMARTGREENS 2016*, Rome, Italy, 23-25 April, pp. 454-461.

[10] Popescu, D., Borza, I., Ensuring the Comfort in the Heated Space by Controlling the Temperature in the Heating Installation of a Non-residential Building, *Proceedings of SMARTGREENS 2016*, Rome, Italy, 23-25 April, pp. 462-467.

[11] Popescu, D., Specific problems on the operation of the automatic control system of temperature into an individual dwelling. *WSEAS TRANSACTIONS on SYSTEMS*, Volume 13, 2014, pp. 482-491