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Application of Wireless Experimental Fuzzy Temperature Control Using MATLAB/Simulink

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Abstract**—*****In this work, wireless experimental fuzzy temperature control of a process simulator is achieved. The process control simulator consists of two main units, an instrument console and a framework carrying the process equipment. In the present study, experimental input/output data is obtained from process control simulator. Heater output temperature is obtained by manipulating heating capacity percent. Fuzzy control algorithm which is written in MATLAB m-file is utilized to wireless temperature control and on-line experiments achieved by using MATLAB/Simulink program. Fuzzy tunning parameters applied for different set temperatures and efficiency of the fuzzy control is observed by calculating the integral of the square of the error (ISE) and the integral of the absolute value of the error (IAE) from experimental results. The wireless experimental fuzzy control comes to the set point much quickly and because of the good results of wireless temperature control experiments this technique can be proposed for the industrial processes. The wireless temperature control is applied to the system successfully and wireless control technique is proposed for various applications which dangerous and can't reach areas easily.***

Index Terms**—Fuzzy control, wireless process control, temperature control, MATLAB/Simulink, process simulator.**

I. INTRODUCTION

Fuzzy control engineering is the earliest and the most application area of fuzzy set theory which is explained by Lotfi A. Zadeh in 1965. The advantage and the best property of fuzzy control does not require analysis and synthesis of the mathematical model of the process. All the control rules are constructed by expert knowledge or operator's experience. In this sense fuzzy control algorithms present many advantages such as simplicity, robustness, no need to find transfer functions, nonlinear behavior and adaptability. The first fuzzy control application belongs to Mamdani and Assilian where control of a small steam engine is considered. Today fuzzy control has been applied various systems such as electrical household, mechanical and robotic systems, power plants, transportation and automotive systems, chemical processes and nuclear reactors [1-3].

Temperature control of chemical reactors is an important objective for achieving higher product qualities. Complex static and dynamic behaviors, system nonlinearity, unavailability of states, multiplicity and instability of equilibrium points and input constraint have made it a challenging problem. Numerous temperature controllers for chemical reactors, based on conventional PID structure and state feedback control technique, have been proposed. Advanced control strategies, like predictive control scheme, have been also used for temperature control of chemical reactors. For instance, some comparisons among these techniques have been made. In addition, back stepping and feedback linearization methodologies are applied either in non-adaptive or adaptive forms. On the other hand, since fuzzy control systems are used as universal approximators with arbitrary accuracy for any real continuous function on a compact set, it has attracted great interests in utilizing heuristic-based approaches to cope with the control problem of nonlinear and ill-conditioned systems. Experimental evaluation of fuzzy controllers for controlling chemical processes has been investigated by researchers [4].

Wireless process control has been a popular topic recently in the field of industrial control. Compared to traditional wired process control systems, their wireless counterparts have the potential to save costs and make installation easier. Wireless technologies open up the potential for new automation applications. Wireless measurements include temperature, pressure, flow, pH, conductivity, gas detection, discretes, level, vibration, valve position etc. [5]. In the present study, experimental input/output data is obtained from process control simulator. Wireless temperature control is achieved by utilizing fuzzy algorithm which is written in MATLAB/Simulink program is used for control experiments. The experimental fuzzy control results of different set points are compared by observing the temperature profiles and calculated ISE, IAE values compared for determining efficiency of fuzzy control algoritm.

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II. EXPERIMENTAL SYSTEM

The process control ssimulator consists of two main units, an instrument console and a framework carrying the process equipment which is shown in Figure 1. The instrument console contains the electronic flow, level, temperature controllers and electrical switchgear. It is connected to the process equipment by several cable assemblies. The process equipment consists of a water tank, water circulating pump, electrical water heater, two vessels, two electrically positioned control valves and a heat exchanger. In process control simulator, twelve manual valves are available for different process experiment loops. In the simulator, temperature measurement and control can be made at four different points which are first tank, heater output, second tank input and output. The system developed for transferring data between the computer and the panel. Data transfer is achieved wirelessly by using the two antenna are found in the laboratory connected to the computer and outside connected to the process simulator. Control valves outputs are connected to the modules, the necessary calibrations are made. The water is pumped via the electrical heater into the reactor up to a certain level. The water then flows back to the sump tank via the cooler. Heat is fed to the water by the heater and residual heat removed by the cooler so as to return the sump tank water temperature to a suitable base level. Heater which is connected on-line to the computer is used as a manipulated variable [6].

Fig. 1 Experimental system: Process simulator, control panel and computer on-line connected to the process simulator with wireless technology

III. TEMPERATURE CONTROL LOOP AND METHODS

The water is pumped via the electrical heater into vessels V1 and V2 in series, thus simulating a reactor vessel with considerable thermal mass. The water then flows back to the sump tank via the cooler. Heat is input to the water by the heater and residual heat removed by the cooler so as to return the sump tank water temperature to a suitable base level. Four thermocouples (T1 - T4) monitor the temperature at different points around the circuit. A selector switch is provided so that any one of the temperatures T2, T3 or T4 can be input to the temperature controller as the process variable. T2 is located at the outlet from the heater and thus provides minimum process response time while T3 and T4 are positioned after V1 and V2 respectively and thus allow the study of systems with greater response times. The selected thermocouple signal is fed into the Eurotherm 3 term temperature controller, the output from which controls the power fed to the heater via two thyristor unit controlling 2 legs of a balanced 3 phase star connected load. The base water temperature is measured by 'T1 at the outlet from the pump. The controller input (process variable), controller output signal and all process temperatures can be recorded on the

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SCADA package. By varying the temperature difference between the control set point and base temperature, the effect of varying system load can be demonstrated [6].

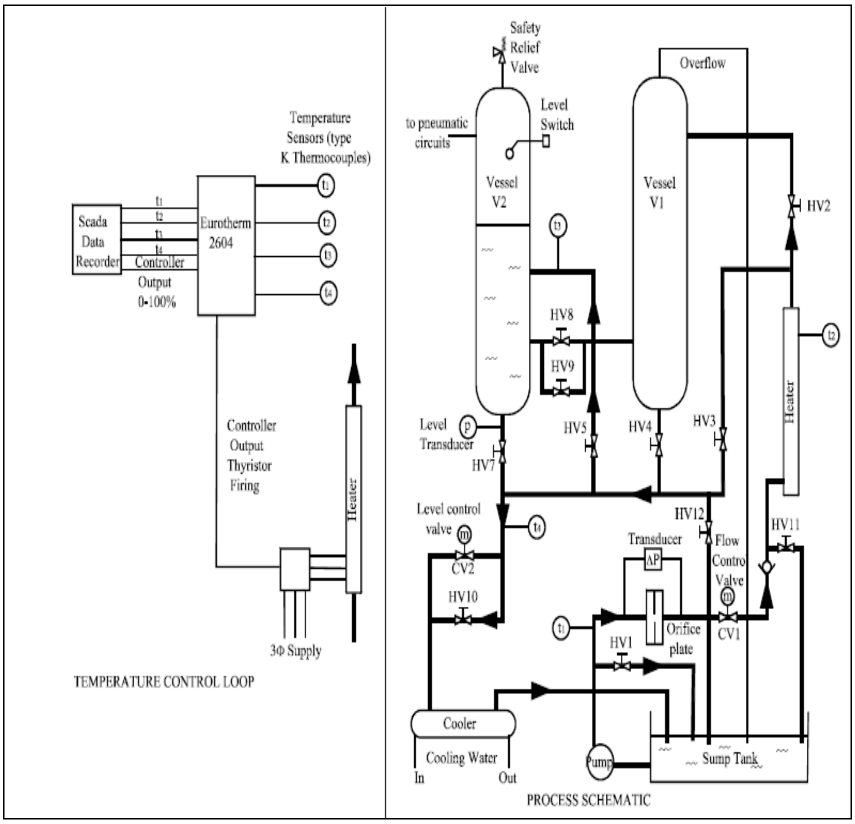

Fig. 2 Temperature control loop and experimental flow chart

First, the steady-state experiments were performed. The fluid flow is obtained by running the pump when the liquid level control valve is opened at a certain level. The cooling water is opened after liquid level is fixed. The heater output temperature (T2) is expected to become at steady-state after 300s, while % heating capacity is on. The temperature is monitored when system has become at steady-state condition. To obtain the desired temperature in the face of set point change, the MATLAB/Simulink program for fuzzy control shown in Figure 3 is used. Wireless fuzzy temperature control algoritm applied using MATLAB/Simulink program for set point 40, 50, 60°C and calculating the integral of the square of the error (ISE) and the integral of the absolute value of the error (IAE) from experimental results.

Important approaches for fuzzy control experiments;

1. Fuzzy control model was adopted first order.
2. Triangle type fuzzy membership functions are used.
3. Triangular type membership functions are assumed to be symmetrical.
4. Number of membership functions for single input-single output (SISO) are chosen as five.
5. For each membership function width of left and right and position of the peak are selected as the parameters to be optimized.
6. The same membership functions are used for input and output but these values are multiplied by the YSCAL and USCAL on the control algorithm for adjustment of scale is made.

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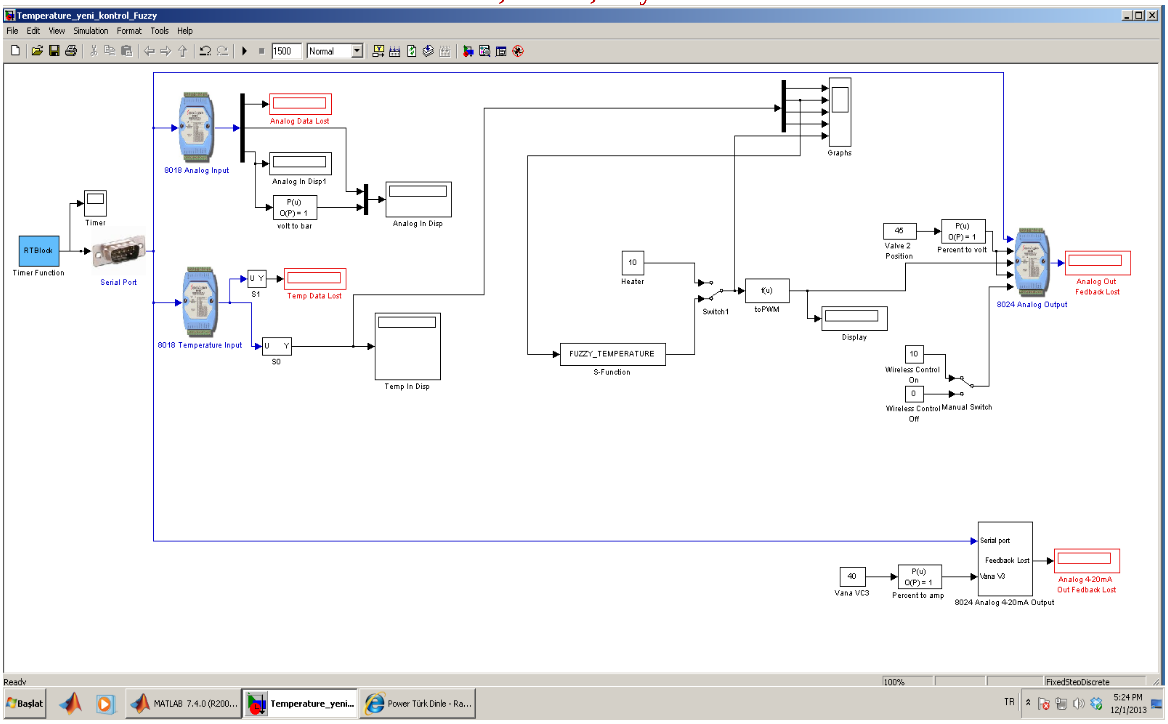

Fig. 3 MATLAB/Simulink program for fuzzy temperature control

IV. RESULTS AND DISCUSSION

All experiments were performed in the same conditions for evaluating performance of the control algorithm and the effectiveness of the control coefficients used in fuzzy control experiments. Performance of the fuzzy control depends on the choice of tuning parameters given in Table 1. Heater capacity changes with time shown in Fig. 4-6-8 for set point 40, 50, 60°C respectively. Temperature changes with time shown in Fig. 5-7-9 for set point 40, 50, 60°C respectively. The efficiency of the fuzzy control algorithm was observed by calculating the performance criteria such as the integral of the square of the error (ISE) and the integral of the absolute value of the error (IAE) from experimental results is given in Table 2.

Table 1. Fuzzy control parameters and functions on the control algorithm

Parameter name	Function on the control algorithm
ULAR	Values of the heater capacity (%)
YSETT	Value of the set point
USETT	Steady-state of heater capacity (%)
YSON	Positive and negative deviate values of temperature
YSCAL	Maximum and minimum difference value of temperature changes
USCAL	Maximum and minimum difference value of heater capacity changes

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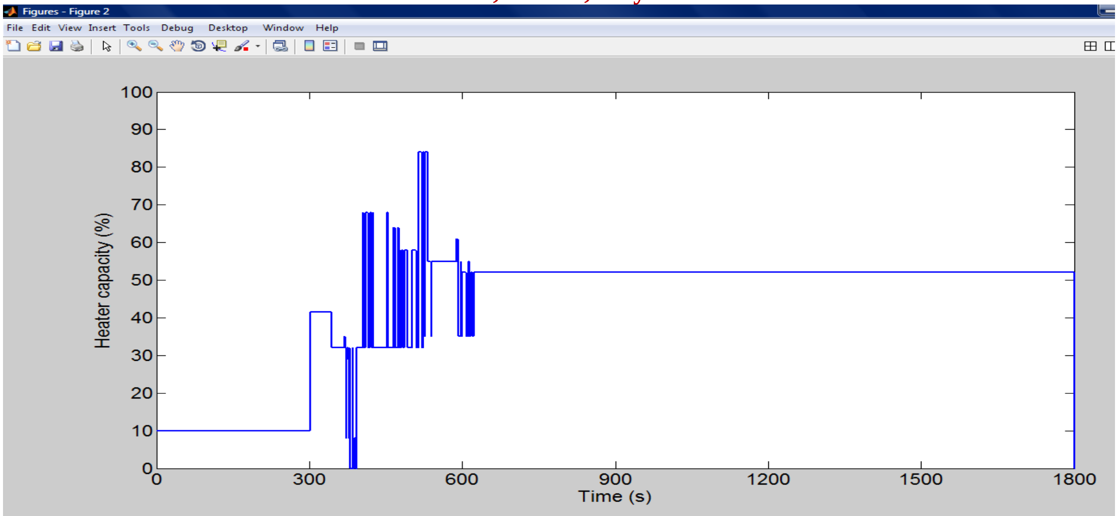

Fig. 4 Heater capacity (%) changes for set point 40°C

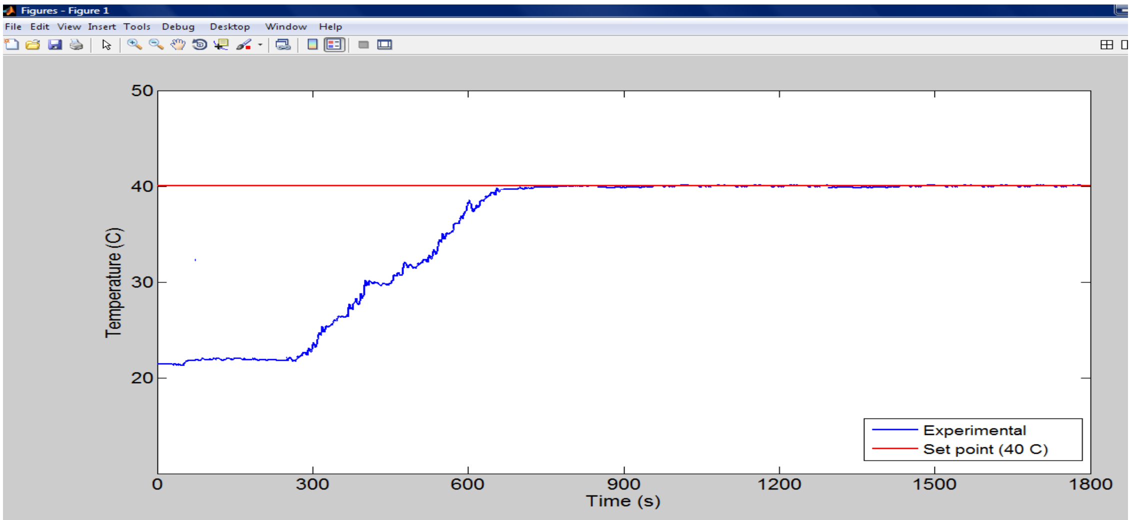

Fig. 5 Temperature changes for set point 40°C

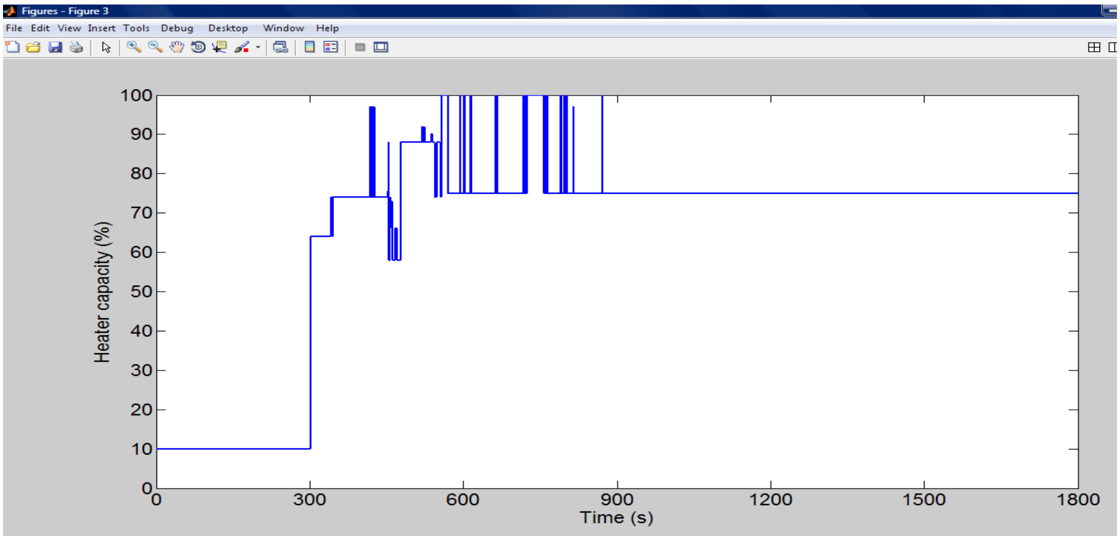

Fig. 6 Heater capacity (%) changes for set point 50°C

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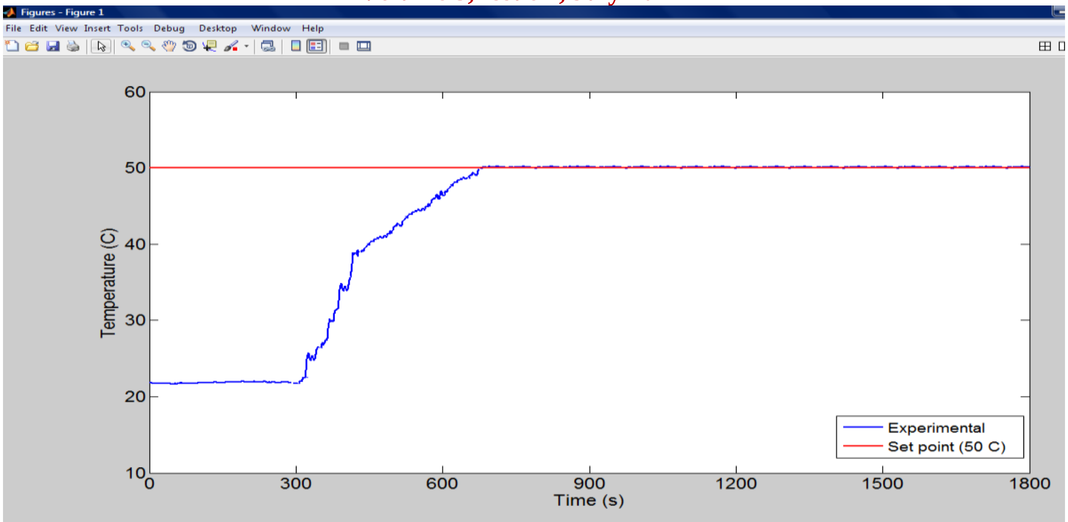

Fig. 7 Temperature changes for set point 50°C

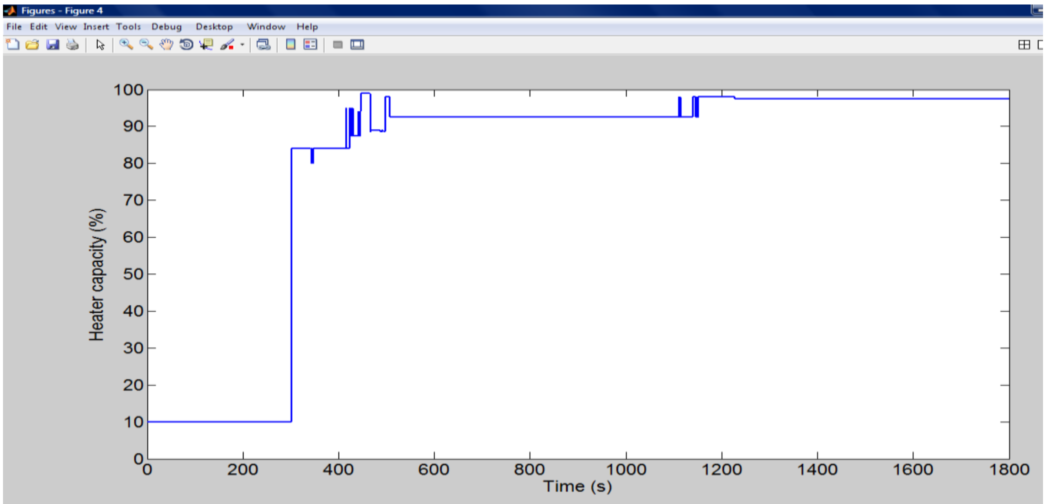

Fig. 8 Heater capacity (%) changes for set point 60°C

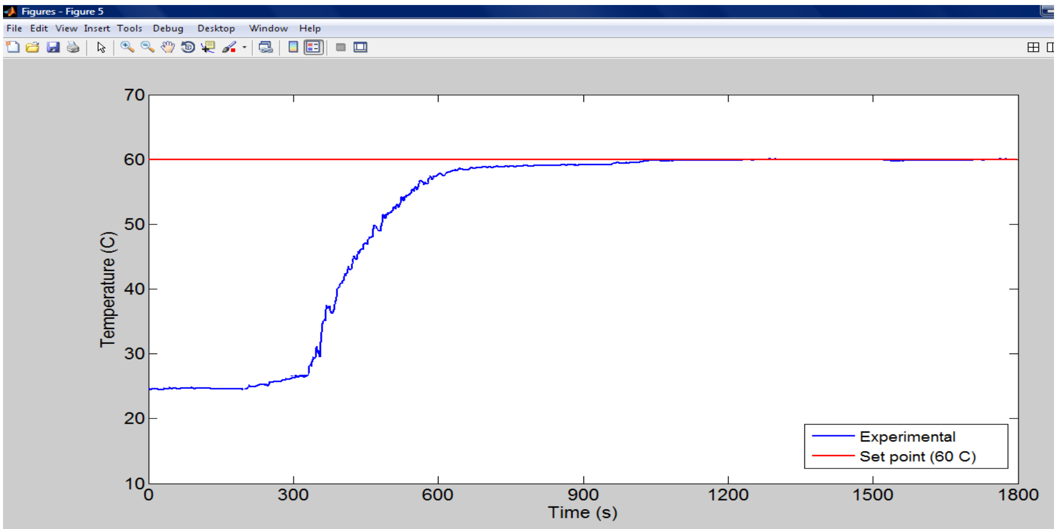

Fig. 9 Temperature changes for set point 60°C

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Table 2. Calculated ISE and IAE values for different set points

	ISE	IAE
Tset=40 °C	11980,86	1293,00
Tset=50 °C	48291,04	3035,20
Tset=60 °C	176791,50	8077,50

The membership functions of the optimal fuzzy control established according to the strings found are presented in Fig. 10-11 for the manipulated and output variable respectively. Using these membership functions, the relation matrix of fuzzy controller was obtain for three different set points.

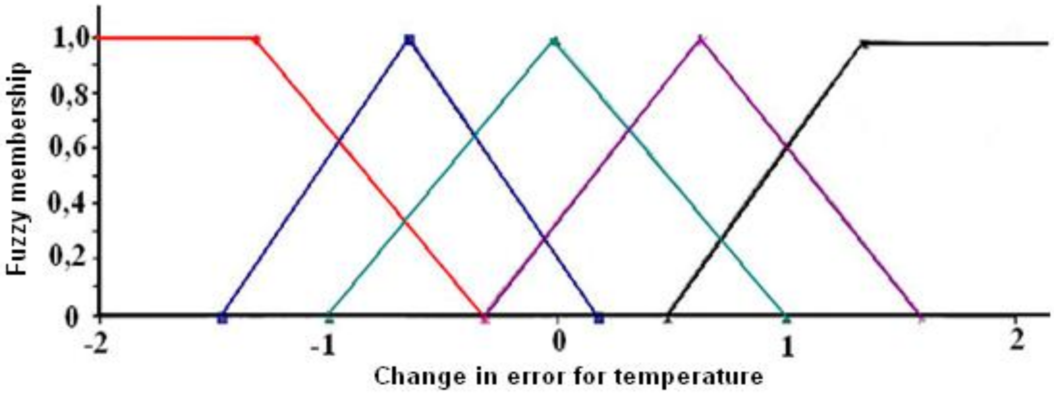

Fig. 10 The fuzzy membership functions for in error for temperature

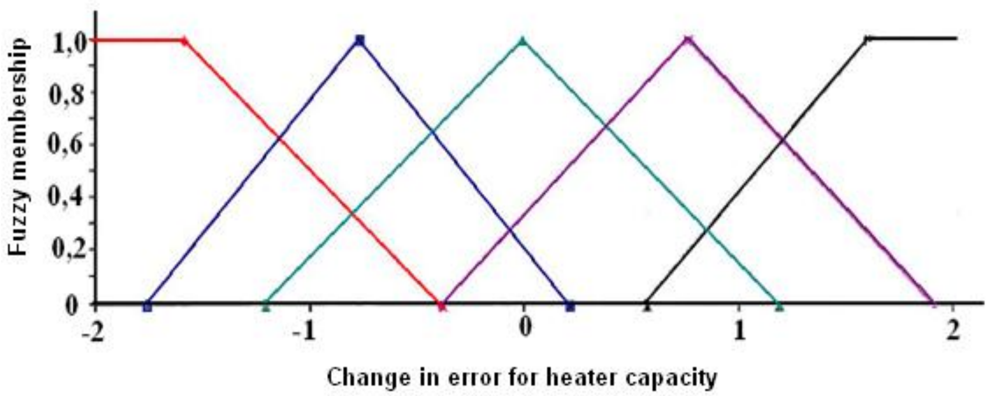

Fig. 11 The fuzzy membership functions for in error for heater capacity

V. CONCLUSION

In this paper, fuzzy control algorithm applied using MATLAB/Simulink program was utilized to experimentally wireless temperature control in a process control simulator. The experimental results show that temperatures come to the set point much quickly. The experimental results with different set points are compared by observing the temperature profiles and calculated ISE, IAE values compared for efficiency of the fuzzy control algorithm. The wireless temperature fuzzy control was applied to the system successfully. Because of the good results of wireless temperature control experiments this technique can be proposed for the industrial processes. Wireless measurement and control applications will be pervasive in the future.

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