REAL-TIME STUDIES ON FUZZY LOGIC CONTROL OF A PLATE HEAT EXCHANGER

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ABSTRACT

Plate heat exchangers are probably the most common type of heat exchangers applicable for a wide range of operating temperatures and pressures. Plate heat exchangers are important components of chemical processes and power industries; they are being increasingly used in petrochemical & pharmaceutical processes due to their highly efficient heat recovery and their compactness.

Due to the importance of the plate heat exchangers, many researchers have investigated the modelling and the optimum design parameters for the system. It is very important to know the behaviour of plate heat exchangers when they are subjected to transient flow and to know the flow variation required to control them when temperature changes take place. In most of the cases modelling of plate heat exchangers is a challenging case due to non-linearity of system. This causes a problem in designing of controller.

In the present work Mamdani type fuzzy logic controller with 49 rules has been developed to a plate heat exchanger and for controlling temperature of plate heat exchanger system, uses MATLAB as a Software for visual modeling tool and simulation research based on SIMULINK. Controlling outlet fluid temperature is main purpose of using heat exchanger where it can transfer heat from a hot fluid to a cold fluid.

The system identification of plate heat exchanger system is carried out by open loop experiment with positive step change in steam flow rate of the system. A transfer function model for the system is obtained from open loop experiment by FOPDT (First order plus Dead Time) analysis with parameter values as Time Constant (τ_p = 54 minutes) , Dead Time (θ_p = 0.34 minute) and steady state gain (Kp) for plate heat exchanger system is 110 [oC/ (kg/min)].

The Fuzzy logic controller is implemented in the Real-Time environment with ARDUINO DUE Hardware interfacing with MTALAB software.

The present advanced FLC controller for the heat exchanger system is then compared with a conventional PID controller. There is less oscillatory behavior with the Fuzzy Logic Controller and faster response, which allows *the system to reach steady-state operating conditions in regions where the PID controller is shows oscillatory and slower response.*

Keywords: *System identification, Fuzzy Logic controller, plate heat exchanger, ARDUINO*

1.INTRODUCTION

Plate heat exchangers are now common and very small brazed versions are used in the hot-water sections of millions of combination boilers. The high heat transfer efficiency for such a small physical size has increased the domestic hot water (DHW) flowrate of combination boilers. The small plate heat exchanger has made a great impact in domestic heating and hot-water. Larger commercial versions use gaskets between the plates, whereas smaller versions tend to be brazed. Plate heat exchangers are important components of chemical processes and power industries; they are being increasingly used in petrochemical processes due to their highly efficient heat recovery and their compactness [3]. Plate heat exchangers are probably the most common type of heat exchangers applicable for a wide range of operating temperatures and pressures. The plate heat exchanger weighs 95% less than comparable conventional shell and- tube exchangers and provide 1000–1500 square meters of heat transfer per cubic meters of exchanger volume [4] .Due to the importance of the plate heat exchangers, many researchers have investigated the modelling and the optimum design parameters for the system. It is very important to know the behaviour of plate heat exchangers when they are subjected to transient flow and to know the flow variation required to control them when temperature changes take place. Dynamic analysis of plate heat exchangers provides information about transient responses subjected to various disturbances. However, there is a limited number of studies that have been reported on the transient analysis and control of plate heat exchangers. Only a few researchers have focused on the control of heat transfer systems such as boiler and plate heat exchangers. Assilian and Mamdani [5] have realized that the fuzzy logic controller could be used not only in the treatment of complex heuristic systems, but it could also be applied to hard systems such as industrial plant controllers. In their report, small boiler steam engine controllers specifying heuristic fuzzy control rules for two feedback loops have been implemented and the results have been compared with those of the Direct Digital Control for different set points. The results show that the quality of control with the fuzzy controller is better than that obtained by the fixed controller.

In the present study, it is proposed to obtain transfer function model of Plate heat exchanger from step response data of experimental work. The design of advanced fuzzy logic controller is proposed to plate heat exchanger system and to implement fuzzy logic control system on real time.

2.IDENTIFICATION OF A PLATE HEAT EXCHANGER SYSTEM

The mathematical model of the plate heat exchanger is obtained from an “OPEN LOOP” experiment performed on the system. The controller is set into the manual mode and a step change either positive or negative is given to the Process. In the present experimental setup, the controlled variable is the “Process Fluid

Temperature". The manipulated variable is "Steam flow rate" to plate heat exchanger. The manipulated variable is changed by the flow control valve. This operates in terms of percentage of opening. Three sets of experiments are carried out with different step changes in the present case to obtain the model of system. The Flow control valve which is steam valve initially set to 10% opening, this corresponds to steam flow rate of 0.2kgs/minute (i.e., plant input) and 35°C of process fluid temperature (i.e., plant output). This indicates the initial steady state of plate heat exchanger system. At this steady state a positive change of 30% valve opening is given to the process by placing the controller in manual mode. The system reaches follows exponential response and reaches new steady state to a temperature of 92°C. The plant input (i.e., steam flow rate) is oscillatory around average value of 0.45kg/min. Similarly. step change of 40% and 50% opening of valve are conducted. The time constant, process gain and dead time are determined using Cohen-Coon (CC) method. Thus, the transfer function model for the Plate Heat Exchanger system is obtained as

$$G_{\text{Plate Heat Exchanger}} = \frac{T(S)}{m(S)} = \frac{110}{54s+1}e^{-0.33s}$$

where, T(s)= Outlet Temperature of cold water, M(s)= Steam flow rate

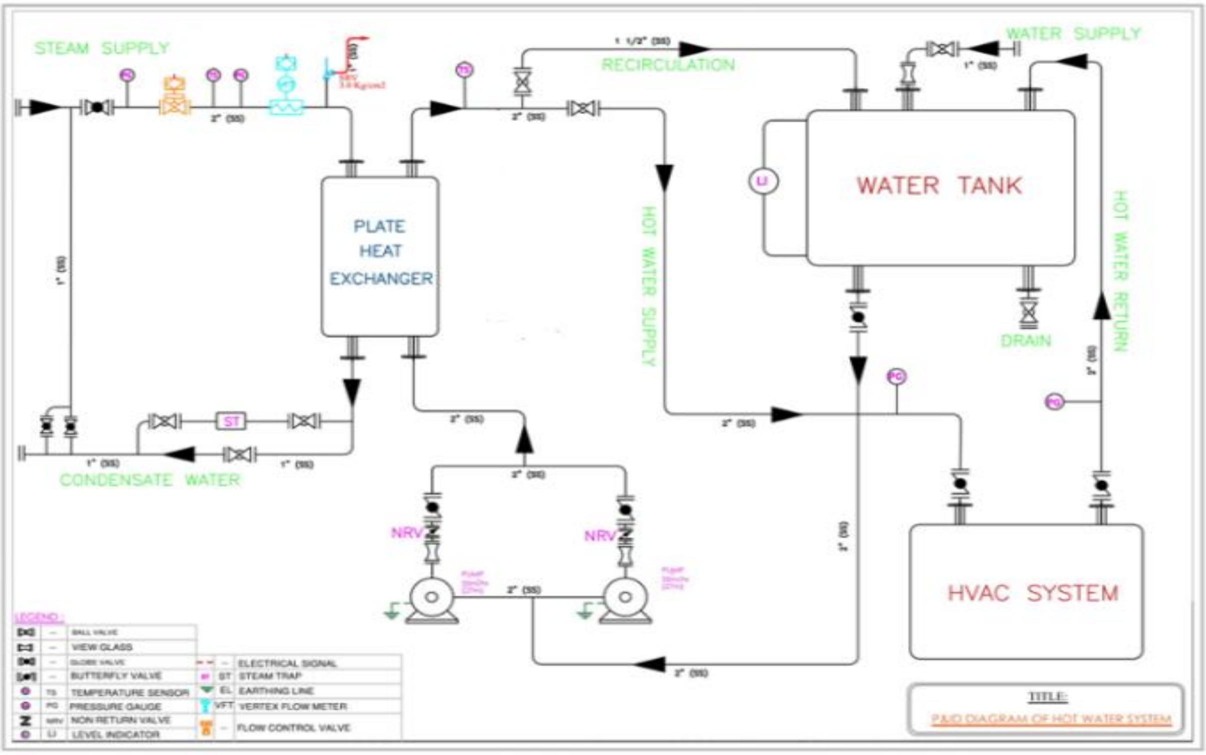
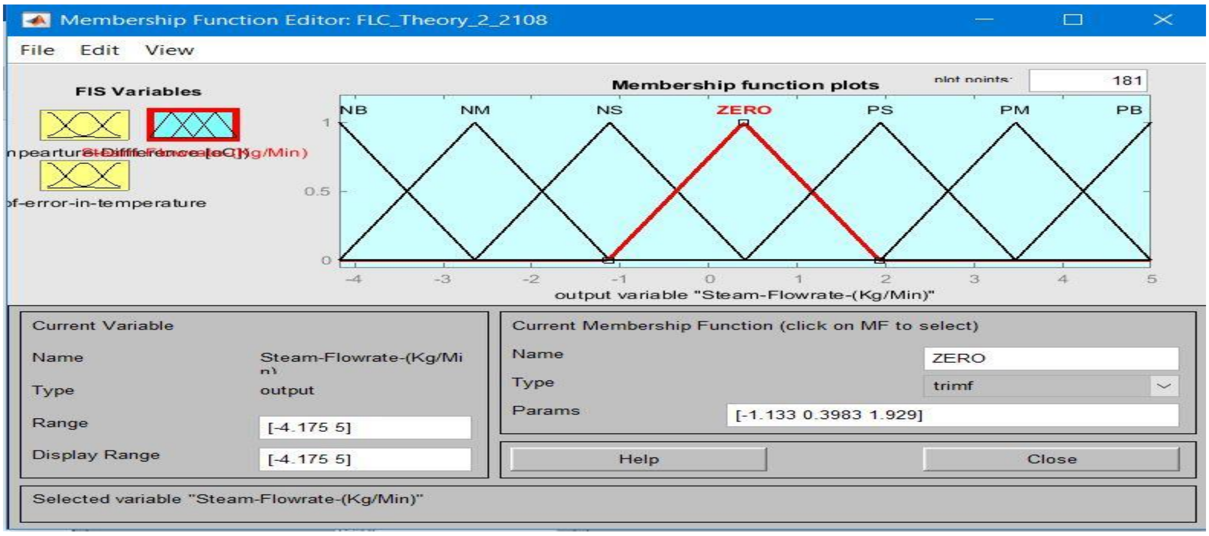


Fig. 1.Schematic diagram of Plate Heat Exchanger system

Fig. 2.Experimental setup of Plate Heat Exchanger system

3.DESIGN OF A FUZZY LOGIC CONTROLLER

The Mamdani type fuzzy logic controller consists of three parts. Fuzzy input variables are error and rate of error of a temperature and fuzzy output is steam flow rate (Figs.3-5). Error and Rate of error are inputs to the controller. Control Action is the output from the Rule matrix (Fig. 6) which given to the process .



Current Variable

Name Steam-Flowrate-(Kg/Min)

Type output

Range [-4.175 5]

Display Range [-4.175 5]

Current Membership Function (click on MF to select)

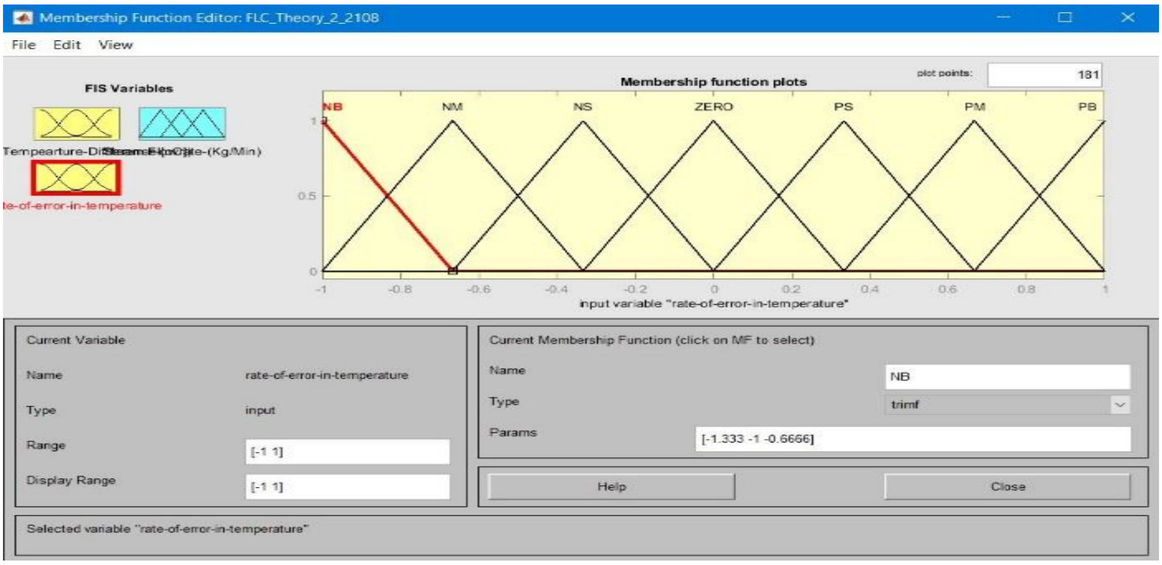
Name ZERO

Type trimf

Params [-1.133 0.3983 1.929]

Selected variable "Steam-Flowrate-(Kg/Min)"

Fig. 3. Membership Function Editor of Control Action Block



Current Variable

Name: rate-of-error-in-temperature

Type: input

Range: [-1 1]

Display Range: [-1 1]

Current Membership Function (click on MF to select)

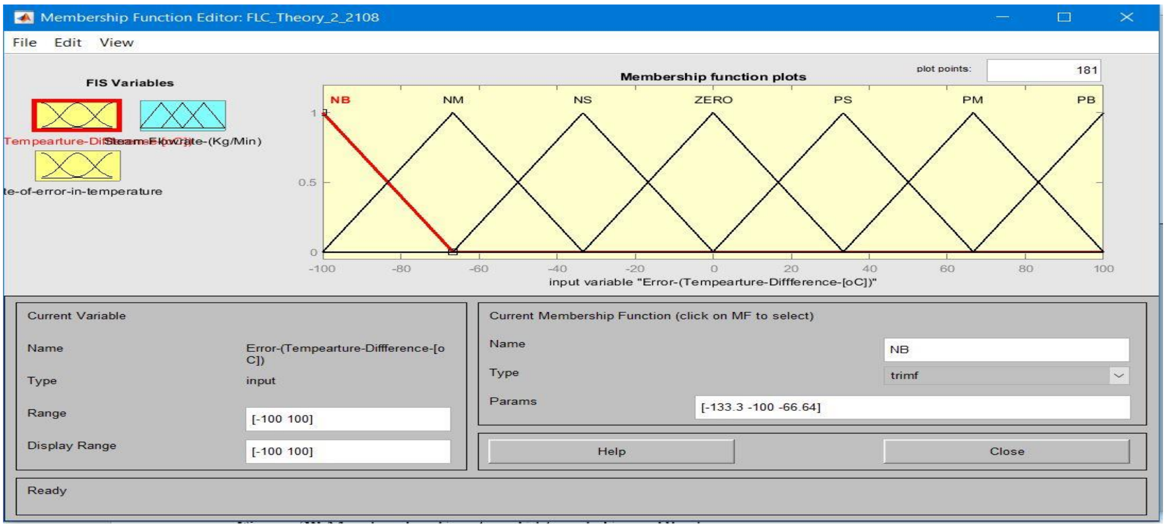
Name: NB

Type: trimf

Params: [-1.333 -1 -0.6666]

Selected variable "rate-of-error-in-temperature"

Fig. 4 Membership Function Editor of Error Rate Block



Current Variable

Name: Error-(Tempearture-Diffference-[oC])

Type: input

Range: [-100 100]

Display Range: [-100 100]

Current Membership Function (click on MF to select)

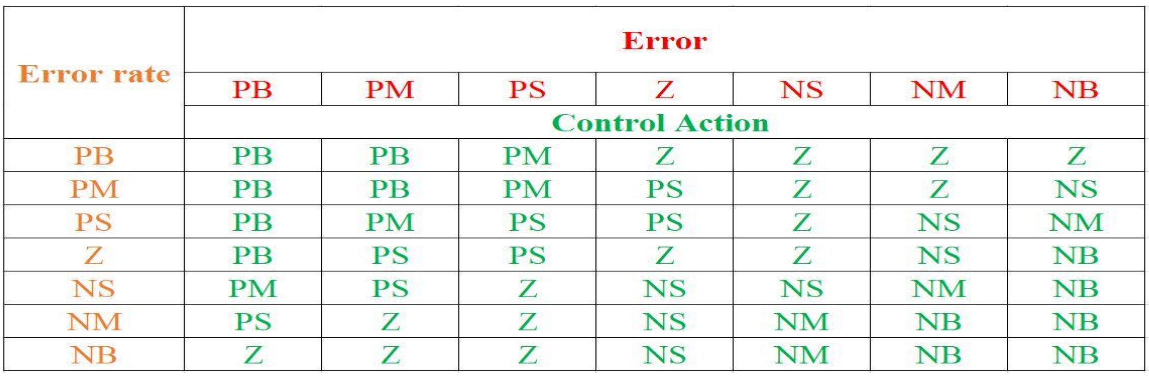
Name: NB

Type: trimf

Params: [-133.3 -100 -66.64]

Ready

Fig. 5 Membership Function Editor of Error Block



Error rate	Error						
	PB	PM	PS	Z	NS	NM	NB
	Control Action						
PB	PB	PB	PM	Z	Z	Z	Z
PM	PB	PB	PM	PS	Z	Z	NS
PS	PB	PM	PS	PS	Z	NS	NM
Z	PB	PS	PS	Z	Z	NS	NB
NS	PM	PS	Z	NS	NS	NM	NB
NM	PS	Z	Z	NS	NM	NB	NB
NB	Z	Z	Z	NS	NM	NB	NB

Fig. 6 Fuzzy Logic Rule Matrix

4.RESULTS AND DISCUSSION

In the present study, performance of fuzzy logic controller is evaluated by both experimentally in real time and theoretically using MATLAB The closed loop simulation diagrams for Fuzzy Logic Control are shown in Fig. 6.

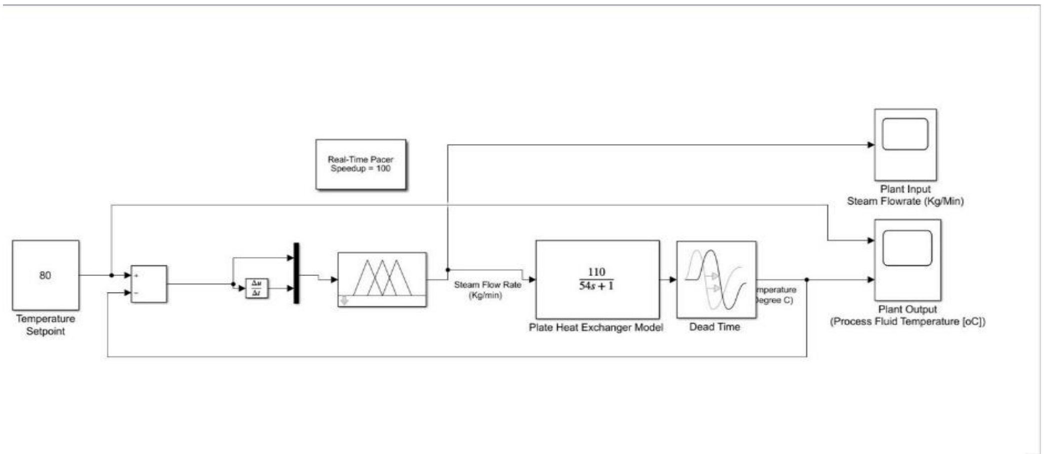


Fig. 7 Closed loop Simulink diagram of Fuzzy Logic Controller

The theoretical closed loop response of the Fuzzy Logic controller are shown in Fig. 8 for a set point of 80°C. Here Fuzzy Logic controller shows faster response and without overshoot.

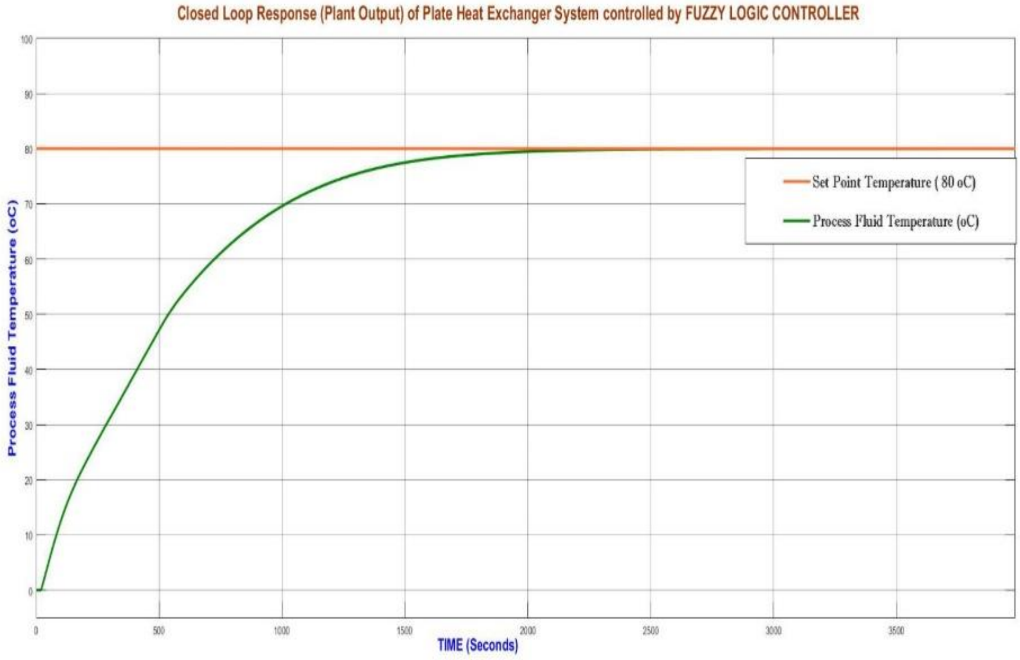


Fig. 8 Closed loop response in temperature of plate heat exchanger with Fuzzy Logic Controller

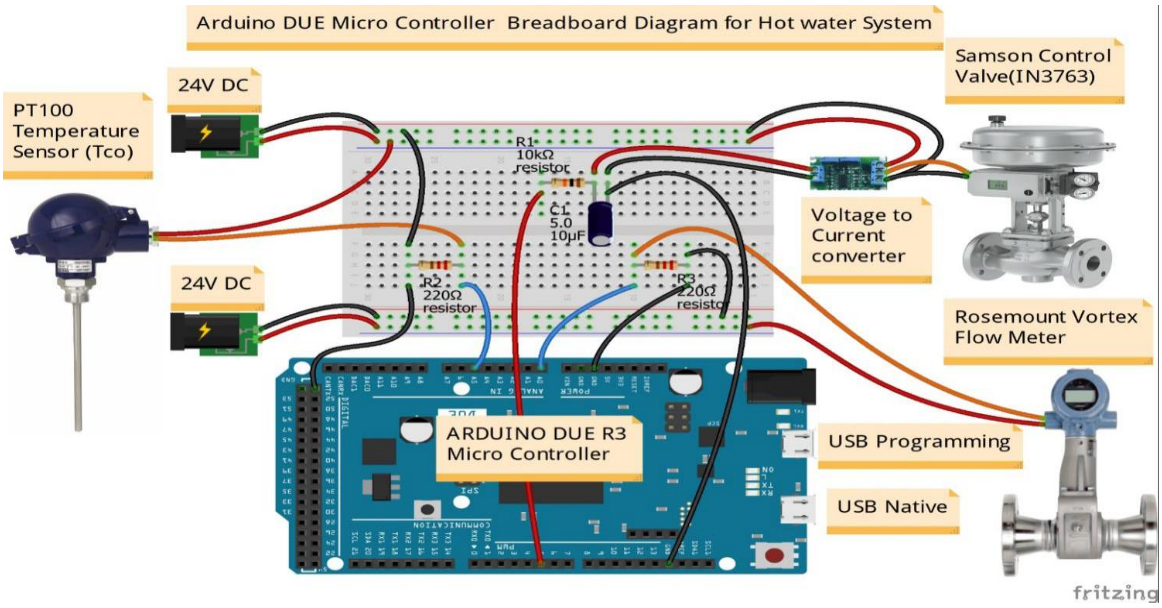


Fig. 9 ARDUINO DUE Hardware set up for Real-Time Control

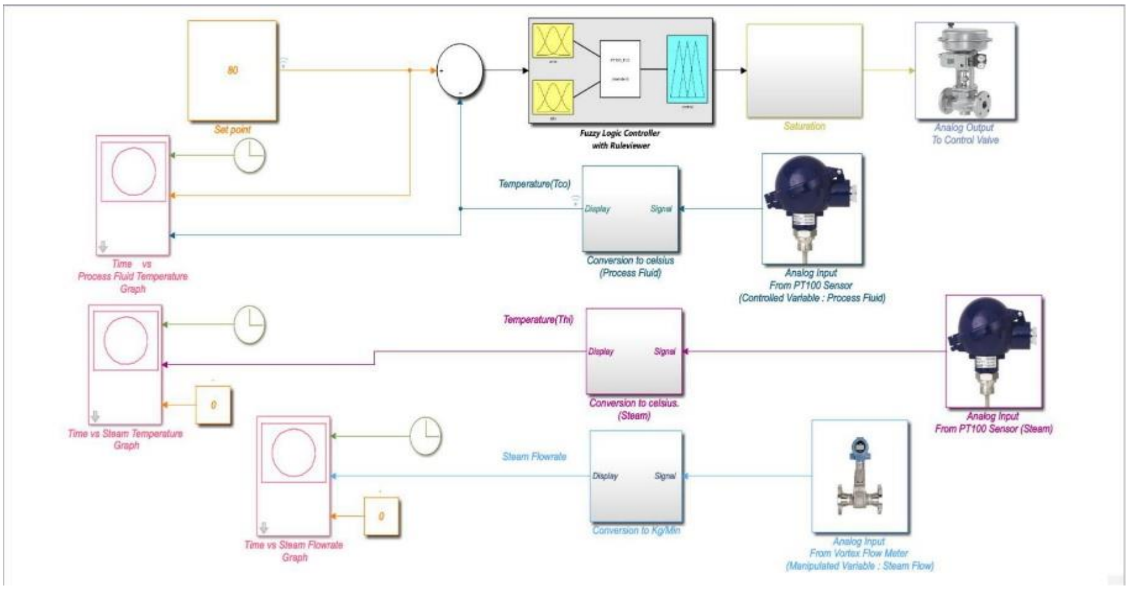


Fig. 10 Block diagram of Closed Loop Feedback Control system of Plate Heat Exchanger system for Fuzzy Logic Controller in Real-Time studies.

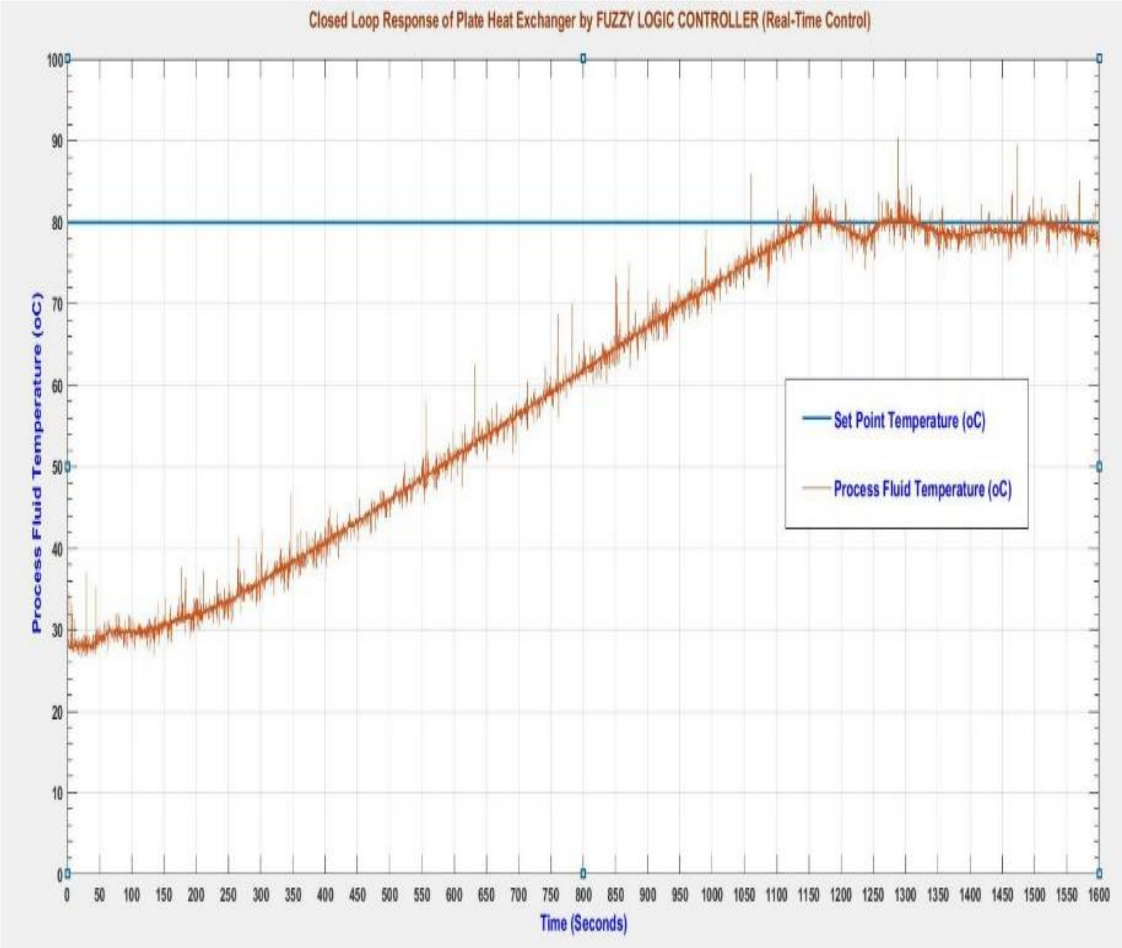


Fig. 11 Closed Loop Response of Plate Heat Exchanger system for positive step change controlled by Fuzzy Logic Controller in Real-Time studies.

The Real-time studies are carried out using ARDUINO DUE Hardware shown in Fig.9 and its block diagram is described in Fig.10. The real-time closed loop response of the Fuzzy Logic controller are shown in Fig. 11 for a set point of 80°C. Similar to theoretical studies, the present Fuzzy Logic controller shows faster response and without overshoot on real-time also.

5. CONCLUSIONS

The transfer function model of plate heat exchanger is obtained by system identification by open loop experiment and is suitable for simulation studies. The Fuzzy Logic Controller is designed is studied theoretically and experimentally for set point changes. Fuzzy logic controller provides superior performance to control the temperature of the system. The system has zero overshoot. The plate heat exchanger system took 22 minutes to reach the set point in experiment and as expected it is same in simulation to reach the set point.

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REFERENCES

1) B.R. Lamb, Plate heat exchangers, a low-cost route to heat recovery, J. Heat Recovery Syst. 2 (3) (1982) 247–255
2) K. Aminian, L. English, D. Patchen, H. Siriwardane, Thermoacoustic liquefaction of coal mine methane to produce LNG for heavy vehicle applications, U.S. Department of Energy Report, Morgantown energy technology centre, 1999.
3) S. Assilian, E.H. Mamdani, An experiment in linguistic synthesis with a fuzzy logic controller, Int. J. Man-Mach. Stud. 7 (1974) 1–13.
3) A.J. Burns, Dynamic system, measurement and control, ASME 3 (1981).
4) M. Ghanim, Dynamics of plate heat exchanger, M.Sc. Thesis, University of Baghdad, Iraq, 1982
5) A.R. Khan, N.S. Baker, A.P. Wardle, The dynamic characteristics of a counter current plate heat exchanger, Int. J. Heat Mass Transfer 31 (6) (1988) 1269–1278.
6) Neeraj Srivastava and Deoraj Kumar Tanti, “MATLAB simulation of temperature control of heat exchanger using different controllers” 2014; 2(1): 1-5
7)] Md. Aftab Alam and Dr. Ramjee Parsad Gupta, “Simulation of Intelligent Controller for Temperature of Heat Exchanger System using MATLAB” Volume||4||Issue||07||July-2016||Pages-5537-5550||ISSN(e):2321-7545
8) M. Chidambaram and Y.S.N. Malleswara Rao, “Nonlinear Controllers for heat exchangers”, *J. Process Control*, 2(1), 17-21 (1992).
9) Salam K. Al-Dawery Ayham M. Alrahawi Khalid M. Al-Zobai “Dynamic modelling and control of plate heat exchanger” Article in Heat and Mass Transfer · November 2012
10) D. Kishore G. Jalalu **“**Control of Heat Exchanger Using Hybrid Fuzzy-Pi’’ 2012 International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 4, Jul-Aug 2013, pp.1396-1400
11)] Md. Aftab Alam Dr. Ramjee Parsad Gupta “Simulation of Intelligent Controller for Temperature of Heat Exchanger System using MATLAB” Volume||4||Issue||07||July-2016||Pages-5537-5550||ISSN(e):2321-7545 Website: http://ijsae.in