Fuzzy Logic Based CSTR Control

Manish Talwar

Assistant Professor, Bharati Vidyapeeth, College of Engineering, New Delhi, India

***Abstract**:* Continuous stirred tank reactor can be thought of as a tank where reactants and products are added and stirred uniformly and simultaneously. This tank is used often in applications such as that of wastewater treatment units (i.e. activated sludge reactors).often the primary requirement of a plant is to control the common parameters like temperature and pressure. If the temperature is not controlled, it may lead to loss of product quality and even lead to life threatening situations in industries. In this paper artificial intelligence technique, fuzzy logic has been applied to control the temperature at which the process in operating. Since function of controllers has been improved using artificial intelligence. Simulation results demonstrate the effectiveness of Artificial Intelligence modeling techniques.

Keywords: Simulation, Artificial Intelligence, Fuzzy Logic Control

I. INTRODUCTION

Process control is a primary branch of engineering dealing procedures, mechanisms and algorithms for checking the output of a plant. This field is widely used in applications like oil refining, paper manufacturing, chemicals, power plants etc. To reduce the risk and economical operation of the process is the requirement of current trends in control processes. To accomplish these requirements strict quality control is required. Using artificial intelligence techniques for these kinds of control processes is an effective tool for control engineer nowadays. Control theory is an interdisciplinary branch that involves the use of control techniques and deals with controlling the temperature of plant. Often an external input known as the reference or the set point (SP) is used in the system. Basically, the controller alters the inputs to the system when one or more than one output variable is observed to follow the reference value for observable time [1-8].

II. CONTINUOUS STIRRED TANK REACTOR

It can be viewed as a Mixing vessel in which reactants are added and mixed and process is controlled using controllers and is used in many chemical processes. These mixing vessels are heated through jacket or coil surrounding the vessel. This heating of the fluids should occur at a certain controlled temperature to achieve the desired results. The modification of power when observed results in altering the current to the heating system or the setting of the output flow from the heating/cooling system.

Physical Modelling of STH [1]

The assumptions taken in the paper are

1) A fluid with constant volume , liquid density and heat capacity
2) Constant Inflow and outflow of fluid

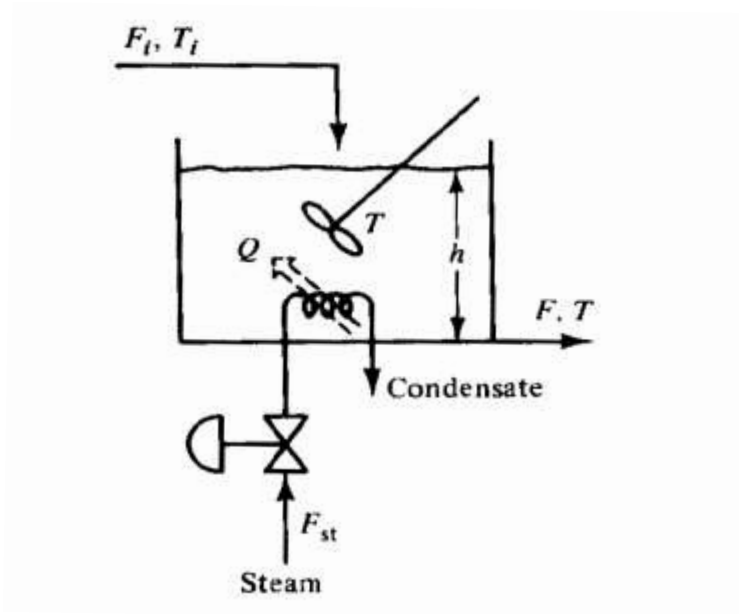

Figure 1: Stirred Tank Heater model [1]

A. Mathematical Equivalent Model of CSTR [1]

Conservation of Mass in the Tank

$$\frac{d(\rho A h)}{dt} = \rho F_i - \rho F$$

Conservation of Energy in the Tank can be deduced as-

$$Ah\frac{dT}{dt} = F_i(T_i - T) + \frac{Q}{\rho c_p}$$

$$Q = UA_t(T_{st} - T)$$

B. Equivalent Simulink Model of STH

From the above equations the Simulink model is drawn. This model of the stirred tank heater is shown below:

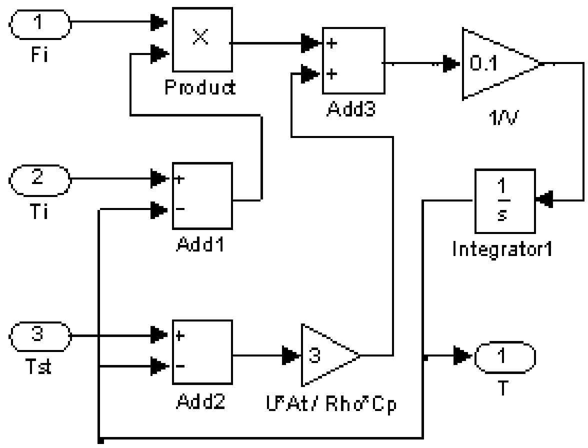

Figure 2: Simulink Model of Stirred Tank Heater

Our objective is to keep the temperature of the tank at 400 ºF under different operating conditions. The simulation is carried out with steam temperature (T_{st}) as the manipulated variable with the PID controller while keeping the input disturbance values to 1 ft^3/min (tank feed flow rate F_i) and 50 ºF (tank feed temperature T_i). The Simulink model of the system is shown below:

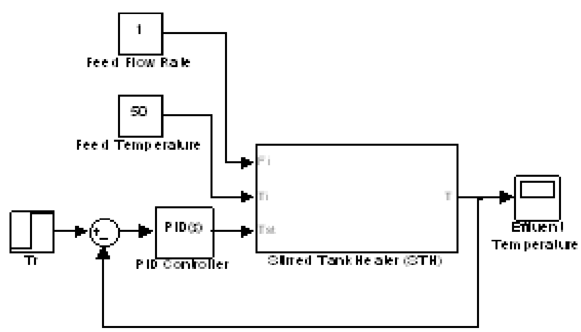

Figure 3: PID Based Simulink Model of STH

PID controllers which are often called the basic building blocks of the process industry has the following form:

$$U(T) = K_p E(T) + K_i \int_0^T E(\tau) d\tau + K_d \frac{d}{dt}(E(T))$$

Where:

U(T) is the observed control output with error

E(T) is defined as E(T)= required value – observed value of the controlled quantity.

K_p, K_i, and K_d are control gains.[9]

III. CONTROL METHOD USED

Fuzzy logic has been used in this paper to maintain the temperature at which process is operating. FIS has been developed to develop the rules and membership function and the results are then simulated using Simulink. Fuzzy logic is an advanced interpretation of multi valued logic useful in developing smart systems.

A. FUZZY LOGIC CONTROLLER

Conventional controllers now can be replaced with intelligent controllers like fuzzy logic controller which generate fast dynamic response. Compared to conventional controller's fuzzy logic controllers are better in complex problem solving. A fuzzy logic controller mainly consist of three section namely fuzzifier, inference engine and defuzzifier.

MEMBERSHIP FUNCTIONS

The input and output membership functions are shown below. The notations used for linguistic levels are NB: negative big; NS: negative small; ZE: zero; PS: positive small; PB: positive big.

Membership function of E(t)[8]

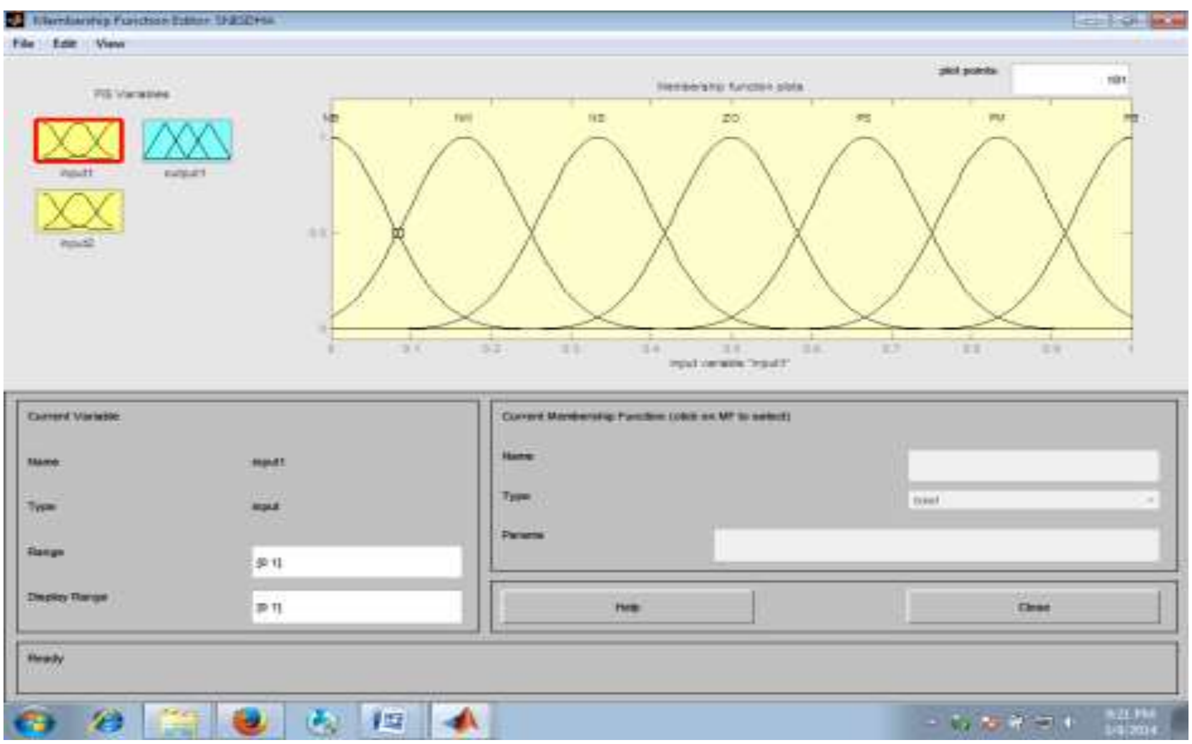

Figure 4 : Membership function

Membership function of de/dt

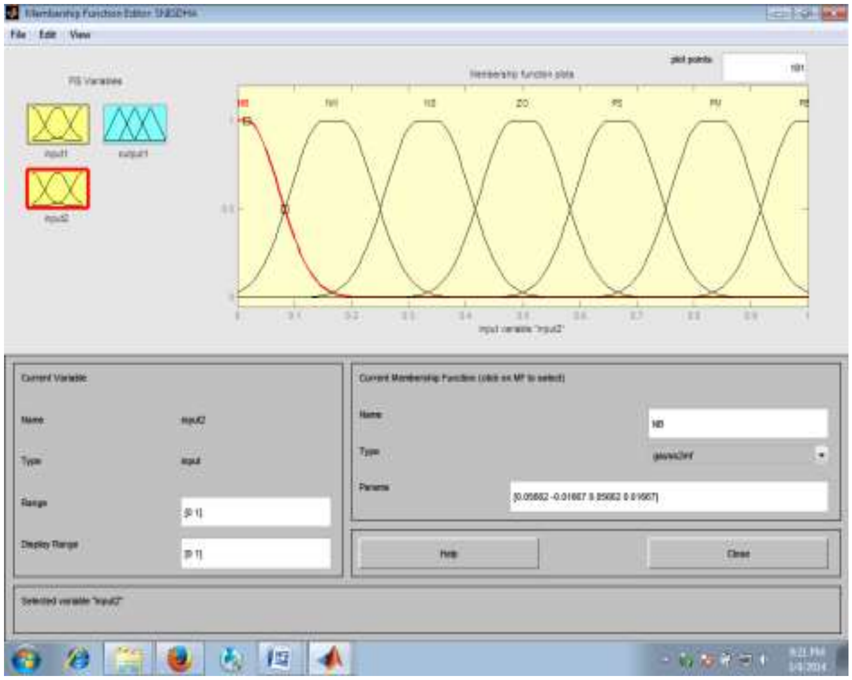

Figure 5: Membership function of de/dt

Membership function of output u(t)

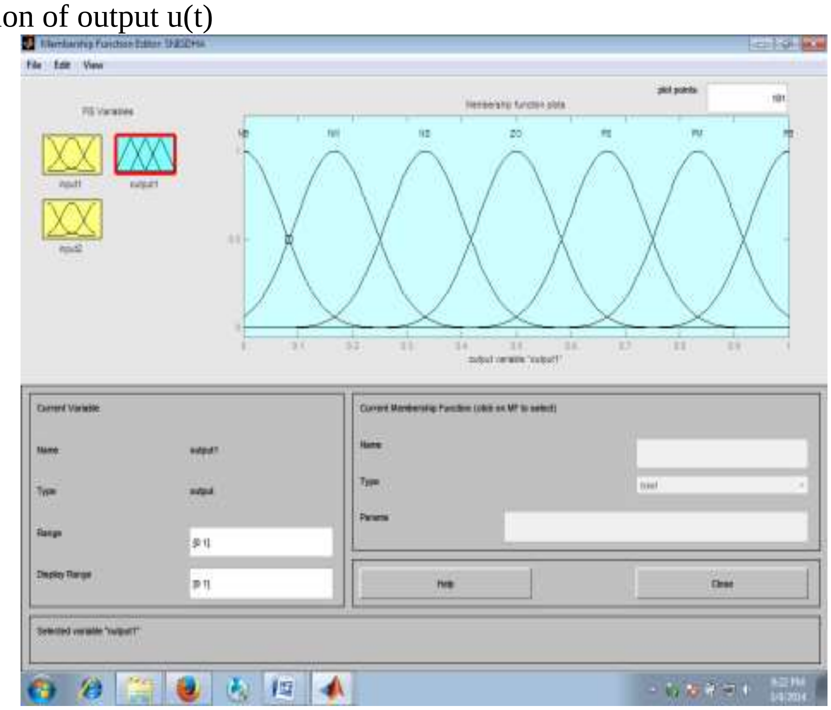

Figure 6: Membership function of output u(t)

Rules in Inference System

The rules defined in fuzzy controller are used to indicate a relation between the input and the output which are obtained by knowledge of the system design. The rules can then be defined by the linguistic variables. All rules governing the mechanism of each output are explained in the following table.

RULE BASE

de/dt	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PM	PB	PB	PB

The names zero, positive, negative are labels of fuzzy. NB, NM, NS, PS, PM,PB(Negative Big, Negative medium, Negative Small, Positive Big and Positive Medium, Positive Small). The above representation is also possible in an economical manner.

RULE VIEWER

For the interpretation of the entire fuzzy process at once and to display a broad outline of the process, rule viewer can be used. The rules defined in above rule base can be converted to statements by use of rule editor and their graphical representation can be seen below where first two columns represent preceding part of the rule and third column represents the consequent part of the rule. [8]

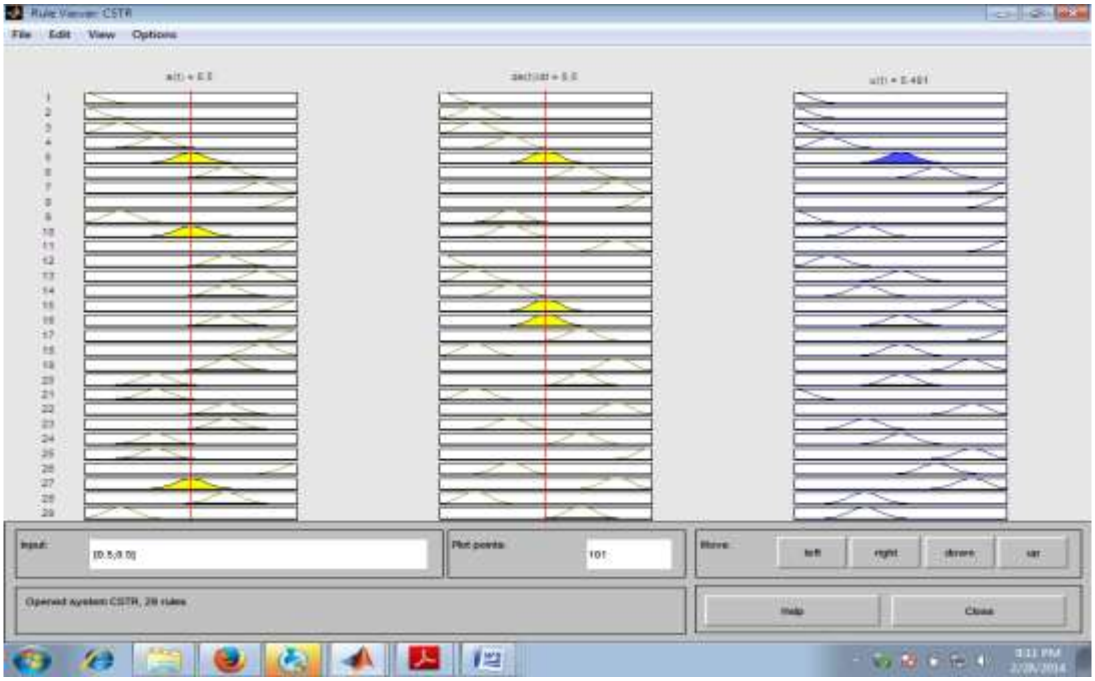

Figure 7 Rule Viewer

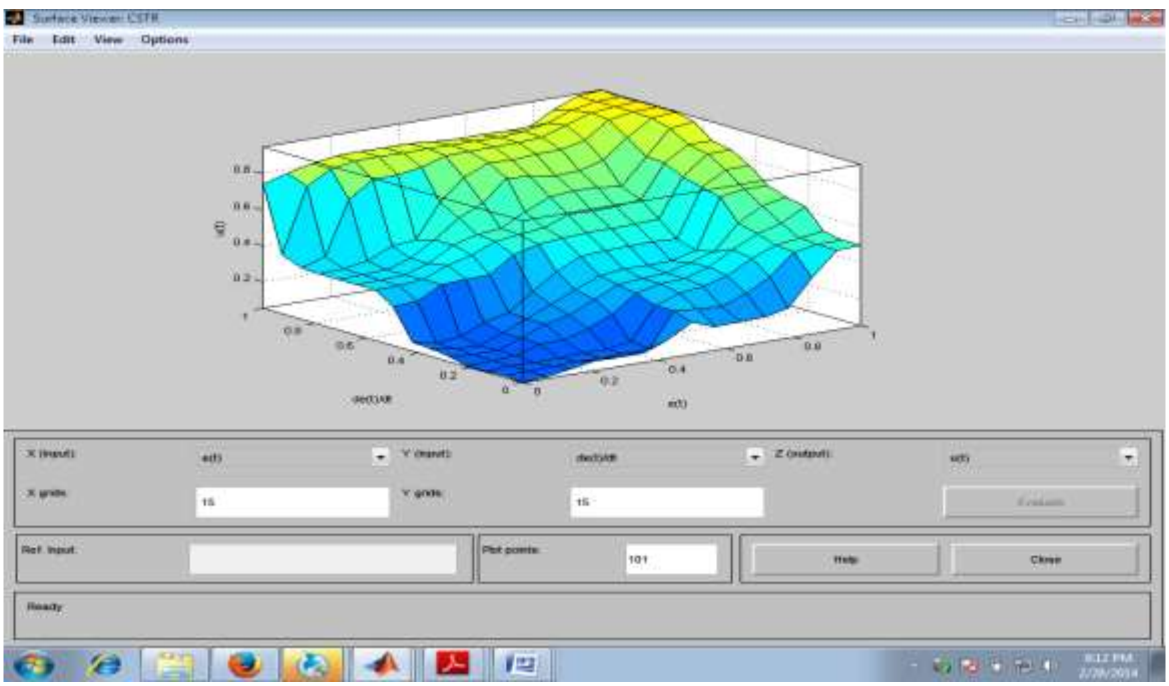

Figure 8 : Surface Viewer [8]

IV. RESULT

Characteristics of Step Response for PID Tuning using Fuzzy Logic

Fuzzy Logic Controller Results	
Rise Time (sec)	0.701
Overshoot (%)	0.78
Settling Time (sec)	1.11

V. REFERENCES

[1] Stephanopoulos, G. (1984). Chemical process control: an introduction to theory and practice.
[2] Smith, C. A., & Corripio, A. B. (1985). Principles and practice of automatic process control (Vol. 2). New York: Wiley.
[3] Katsuhiko Ogata, "Modern Control Engineering", 4th Edition, Prentice Hall India, 2006
[4] Available at: https://en.wikipedia.org/wiki/Fuzzy_logic
[5] Morari M., E. Zafirion, "Robust Process Control", Prentice Hall International, Englewood Cliffs, NJ, 1989
[6] Zulfatman, M.F. Rahmat, "Application of Self Tuning Fuzzy PID Controller on Industrial Hydraulic Actuator Using System Identification Approach", International Journal on Smart Sensing and Intelligent Systems, Vol. 2, No. 2, June 2009
[7] Abdur Raquib Ridwan, Ishtiza Ibne Azad, Md. Ibnea Sina Bony, "A Simulink Modeling to Develop a Control System of Stirred Tank Heater with Multifarious Operating Conditions", International Journal of Computer Applications (0975 – 8887), Vol. 57 – No. 21, Nov. 2012
[8] Available at: www.mathworks.in/products/fuzzy-logic
[9] Available at: https://en.wikipedia.org/wiki/PID_controller