Self Adaptive Design Implementation of Auto Tuning Algorithm for PI Controller in Real Time pH Neutralization Plant Operation

Naregalkar Akshay[1], Syed Suhail Ahmed Ali[2],

[1] *Asst. Professor ,Department of EIE, VNR Vignana Jyothi Institute of Engineering & Technology, Hyderabad, India*
[2] *M.Tech.,Department of EIE, VNR Vignana Jyothi Institute of Engineering & Technology, Hyderabad, India*

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Abstract - *Effective treatment of waste water is very essential in industries due to their harmful effects.it is essential to maintain pH in neutral region as per titration curve indication of strong acids which shows a small change in input, gives huge change in output in the range 6-8 pH value. Also there should be detection and correction of non-linear characteristics and disturbances such as temperature variations that occur in real time plant scenario.*

This paper aims to reduce these real time disturbances that effect the pH value and prevent pH operating point in the neutral region. This work involves design of algorithm to choose a suitable tuning method for different plant characteristics and then to tune controller parameters effectively. The tuning methods selected were Ziegler-Nichols method, Astrom-Hagglund method, Tsang-Rad method and Fruehauf tuning rules were applied for PI (Proportional Integral)tuning. This makes adaptive tuning of PI Controller in different plant parameters and disturbances.

Key Words: **Adaptive Tuning , Auto Tuning , PI Controller , pH neutralization , algorithm, real time .**

1.INTRODUCTION

Neutralization, is the chemical reaction in which an acid and a base react quantitatively with each other. In a reaction in water, neutralization will result in there being no excess of hydrogen or hydroxide ions present in solution. The pH of the neutralized solution will depend on the acid strength of the reactants. Neutralization is used in many applications.

Acidic and basic solutions are usually considered toxic. hence the waste coming out of industries be it acidic or basic its pH must be brought to neutral zone to reduce the toxicity and minimize its effect on the surroundings where it is released or dumped, therefore the neutralization process is to be controlled so that any magnitude of pH can be brought to neutral zone and with minimum usage of resources so that no investment losses are incurred[1],[2]. The control action in most of the industries is carried out using a PID controller.

2. Problem Formulation:

Effective treatment of waste water is very essential in industries due to their harmful effects. It is essential to maintain pH in neutral region as per titration curve indication of strong acids which shows a small change in input, gives huge change in output in the range 6-8 pH value. Also there should be detection and correction of non-linear characteristics and disturbances such as temperature variations that occur in real time plant scenario. So to maintain pH operating point in the neutral region, selection of PID controller parameters is very essential in different conditions under varying parameters. So an algorithm is required to choose a suitable tuning method for different plant characteristics and then to tune controller parameters effectively[3],[10].

3. PLANT UNDER STUDY:

The real time system/plant under study is a pH neutralization plant as shown in Fig.1.

Fig-1: Plant Under Study

In this plant , pH control is done by adding the acid or alkali solution based on the set point. If the set point is at acid level, adding a slight excess of acid reactant (V1) makes a large relative pH change in the final concentration of the process tank reactant. The reaction is taken in a stirred tank. Similarly if the set point is at base level, adding a slight excess of base reactant (V2) makes the relative pH change in process tank. If the set point below 7 pH, only acid control valve is enabled to operate. Unless, alkaline control valve is activated. pH electrode output signal from signal conditioning circuit is 4 – 20 mA current. This current signal is given to DAQ card and then to PC .Depending upon Error signal and control parameters, PID controller generates a control signal. This control signal is given to DAQ Card which gives 4-20mA current signal to actuator for varying flow of the alkaline or acidic fluid into tank to achieve desired pH.

4. ANALYSIS OF TUNING METHODS USED:

The following four tuning methods were used in this paper for analysis and implementation of algorithm[4],[5]:

1.Ziegler-Nichols

2.Astrom-Hagglund

3.Tsang-Rad

4.Fruehauf

4.1 ZIEGLER-NICHOLS TUNING:

The Ziegler–Nichols tuning method of tuning a PID controller is done in only P-mode. Then the gain Kp is increased such that the process output becomes unstable and continuous oscillations occurs .This gain is critical or ultimate gain Ku and the oscillation time is Tu .These two parameters are used to find the P, I, and D gains .as per Z-N tabulations.[8],[9].

Thus this method is used for finding out PID controller parameters.

4.2 ASTROM AND HAGGLUND TUNING METHOD:

This is a relay tuning method. This method does not introduce loop instability like the Ziegler-Nichols tuning method and a little plant knowledge is only enough to keep plat output nearer to set point. This method uses relay feedback to get oscillatory response. In the test ,first, a relay feedback test is performed to measure frequency, amplitude, and plant gain. And later a set of PID-type controller parameters is formulated.
This tuning method mainly uses cost function gradient / weighting functions filter function to get desired parameters. The formulae are as follows:

$$K_c=.809/K_m,\ T_i=T_m \qquad (2)$$

4.4 FRUEHAUF TUNING METHOD:

This tuning method is applicable to integrating processes and uses IMC structure to obtain the tuning parameters. The expression for a PI controller in this tuning method are:

$$K_c=5/9K_m, T_i=5T_m \qquad (3)$$

5. PROPOSED ALGORITHM FOR SELECTION OF SUITABLE TUNING METHOD:

The system was modelled using PRC method and different tuning methods were applied to the process while also making changes in the gain and the time constant of the process keeping in mind that any disturbance to the system can only effect these 2 parts of the transfer function.
The purpose of the above procedure is to decide which tuning method works best for a specific change in the transfer function due to various disturbances that affect the process.
Process transfer function[6],[7] was obtained as follows:

$$TF=(7.0921/8.545s+1)\exp(-1.71s) \qquad (4)$$

The above four equations from 1-3 are used to find PI Controller setting for the actual plant described by equation 4. The following flow chart(Fig.6) describes the steps involved in implementation of proposed algorithm .Then as per the flow chart , proposed algorithm is implemented using LabVIEW software environment as shown in Figure 2-5 .

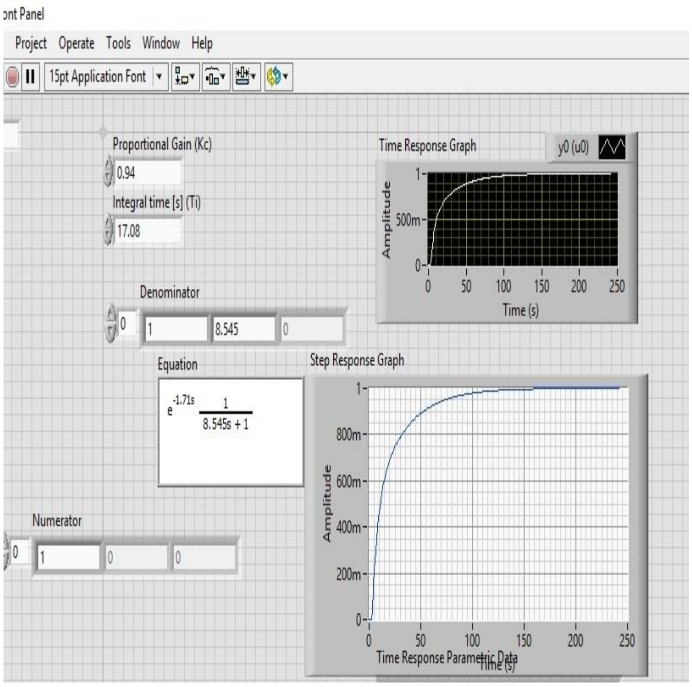

Fig-2: Time Response of System for AH tuning methods

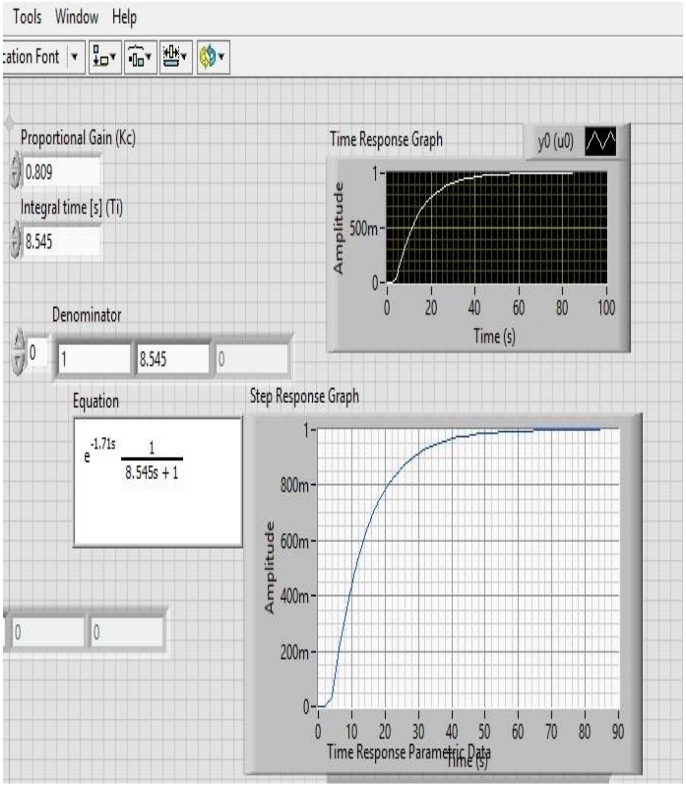

Fig-3: Time Response of System for TR tuning methods

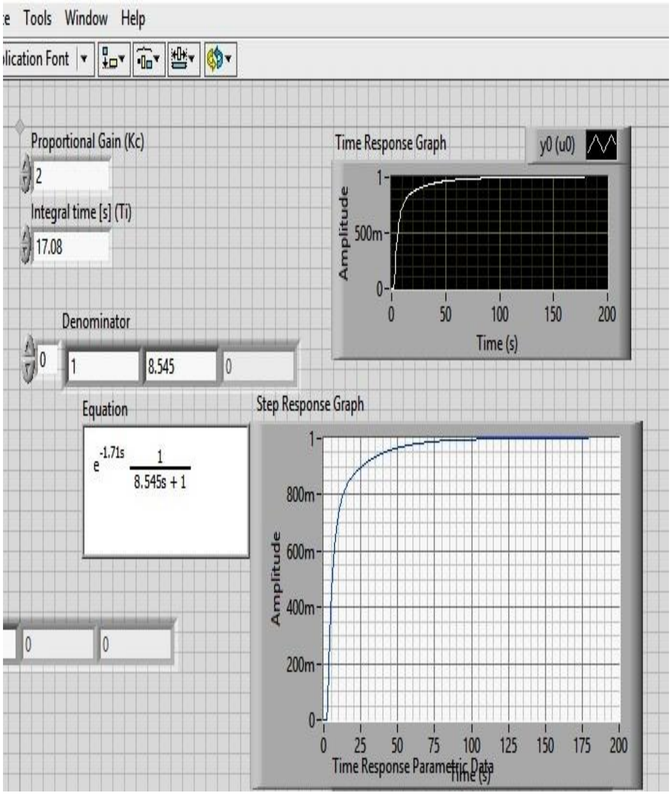

Fig-4: Time Response of System for ZN tuning methods

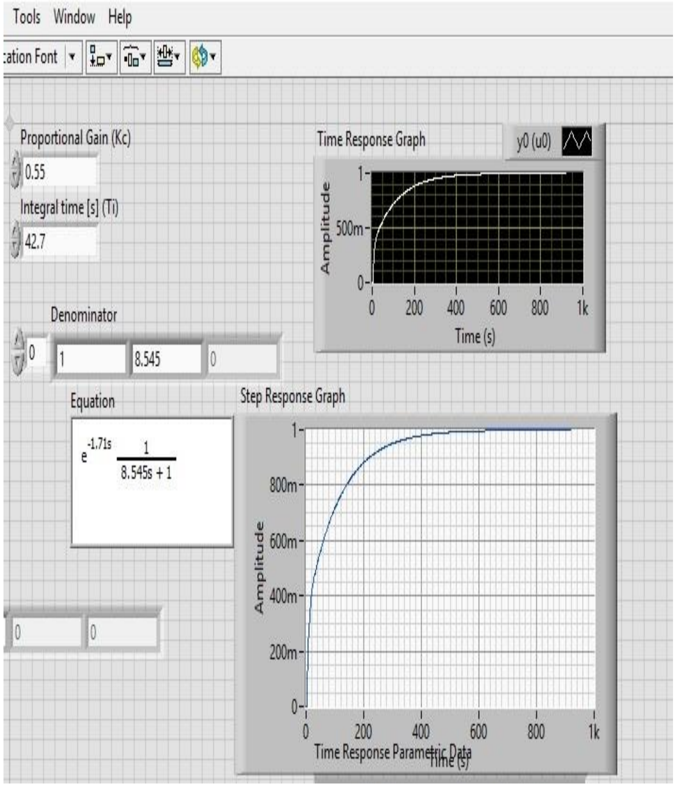

Fig-5: Time Response of System for FF tuning methods

6. RESULTS AND ANALYSIS:

The PI Controller parameters are tuned under different plant parameters effectively with selection of suitable tuning method. Then the plant output is controlled accordingly to reach the desired response.

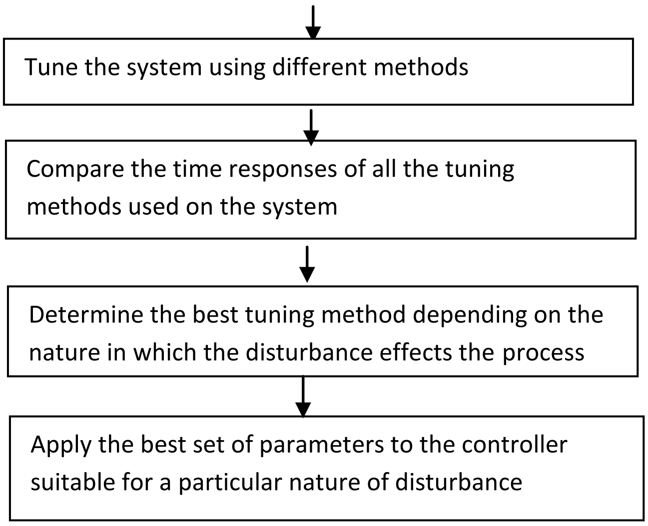

Fig-6: Algorithm Implementation Flow Chart

The comparison results were obtained are as shown in tables:

Table -1: response for actual transfer function

Plant gain G=7.0921,Plant Time Constant TC=8.54				
Tuning method	Ziegler-Nichols	Astrom-Hagglund	Tsang-Rad	Fruehauf
Tr(sec)	22.29	48.56	23.23	2333.42
Ts(sec)	76.72	121.92	52.81	521.9

Table -2: Low gain response

Plant gain G=1, Plant Time Constant TC=8.54				
Tuning method	Ziegler-nichols	Astrom-Hagglund	Tsang-Rad	Fruehauf
Tr(sec)	22.19	48.5	23.23	214.29
Ts(sec)	76.38	122.77	52.81	483

Table -3: High gain response.

	Plant gain G=50, Plant Time Constant TC=8.54			
Tuning method	Ziegler-nichols	Astrom-Hagglund	Tsang-Rad	Fruehauf
Tr(sec)	22.19	48.5	23.23	214.29
Ts(sec)	76.38	122.77	52.81	483

Table -4: Small time constant response

	Plant gain G=7.0921, Plant Time Constant TC=1			
Tuning method	Ziegler-nichols	Astrom-Hagglund	Tsang-Rad	Fruehauf
Tr(sec)	2.68	5.68	2.71	27.47
Ts(sec)	10.51	15.85	7.66	62.65

Table -5: Large time constant response

	Plant gain G=7.0921, Plant Time Constant TC=50			
Tuning method	Ziegler-nichols	Astrom-Hagglund	Tsang-Rad	Fruehauf
Tr(sec)	130.53	284.33	135.97	1373.64
Ts(sec)	441.53	707.81	296.66	3048.65

7. CONCLUSIONS

It was found that ZN method gave most satisfactory rise time and TR method gave the most satisfactory settling time where as the better settling time was obtained at the cost of increased delay compared to ZN method. It was also observed that FF method almost entirely eliminated the delay but gave unsatisfactory rise and settling times. Thus the implemented algorithm selects suitable tuning methods under different plant conditions and controls the plant effectively.

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