Fuzzy Logic Controller Operated Water Treatment Plant

Dheeraj Sen
Instrumentation Eng
GECA
Ajmer, India
dsen0610@gmail.com

Hemant Soni
Instrumentation Eng
GECA
Ajmer, India
hemantsoni101998@gmail.com

Kamlesh Rawat
Instrumentation Eng
GECA
Ajmer, India
kamleshrawat483@gmail.com

Rakshita Dhar
University of Glasgow
Glasgow, UK
rakshitadhar@yahoo.com

Shahrukh Khan
CoE-CNDS, VJTI
Mumbai, India
srk08khan@gmail.com

Faruk Kazi
VJTI
Mumbai, India
fskazi@vjti.org.in

***Abstract*- In this paper, Fuzzy logic controller operated water treatment plant is implemented in Emerson's DeltaV distributed control system using MQ controller. This treated water can be used for domestic purposes for e.g. washing vehicles, utensils & clothes and gardening etc. The response of PID controller and FLC (fuzzy logic controller) are compared. Analysis of maintaining tank water level, temperature and water flow rate by both the controllers is done on actual setup.**

Keywords- Distributed Control System, Proportional Integral Derivative (PID), Fuzzy Logic Controller (FLC)

I.INTRODUCTION

Waste water treatment was done in ancient times by sand filtration methods and chlorination of water. As the technology advances new methods to treat waste water are adapted requiring less human effort [1].

In 21st century, large scale waste water treatment plant are functioning on automation using DCS (distributed control system). Compared to programmable logic controller (PLC) distributed control system can perform advanced regulatory control. For example Emerson's DeltaV MQ Controller has advanced control function blocks such as PID, FLC (fuzzy logic controller) [2].

This paper is a practical implementation of a nonlinear FLC, it can outperform a traditional linear PID controller by changing fuzzy rule design or fuzzy membership functions as mentioned in [3].In this process, the waste water treatment plant was controlled by PID controller and FLC controller both. Their responses were compared and analyzed. Both the controllers were tested on a water treatment plant test bed. The process of water treatment plant test bed is a small one described below. The process is known as acid dosing.

A schematic diagram of waste water treatment plant is shown in fig. 1. Waste water treatment plant have 5 tanks – Reservoir tank, waste water tank (WWT), chemical tank (CT), cooling water tank (CWT) and treated water tank (TWT).

The reservoir used to store the water supplied from treated water tank (TWT) via a pump. The water which needs to be treated is supplied via pneumatic valve into WWT. This waste water is pumped using ABB drive (variable frequency drive) installed in control panel. This paper has taken work further ahead of [4] and implementation FLC using VFD hardware is successfully performed.

It's added to liquid in chemical tank by dosing pump and this mixture is supplied into heat exchanger. Chemical tank contains the chemical/ acidic water which is continuously heated by heater installed in CT. Cooling water tank (CWT) tank contains cool water which is basically used for making the hot water cooled. This process is done in heat exchanger where there are two supplies; one is the acid dosed hot water and second is the cooling water supplied from CWT tank.

In this process the principle of heat exchanging is being used. So the energy from hot water get exchanged to cool water and treated water is bought down to normal

978-1-7281-3958-6/19/$31.00 ©2019 IEEE

Authorized licensed use limited to: University at Buffalo Libraries. Downloaded on December 02,2021 at 23:24:45 UTC from IEEE Xplore. Restrictions apply.

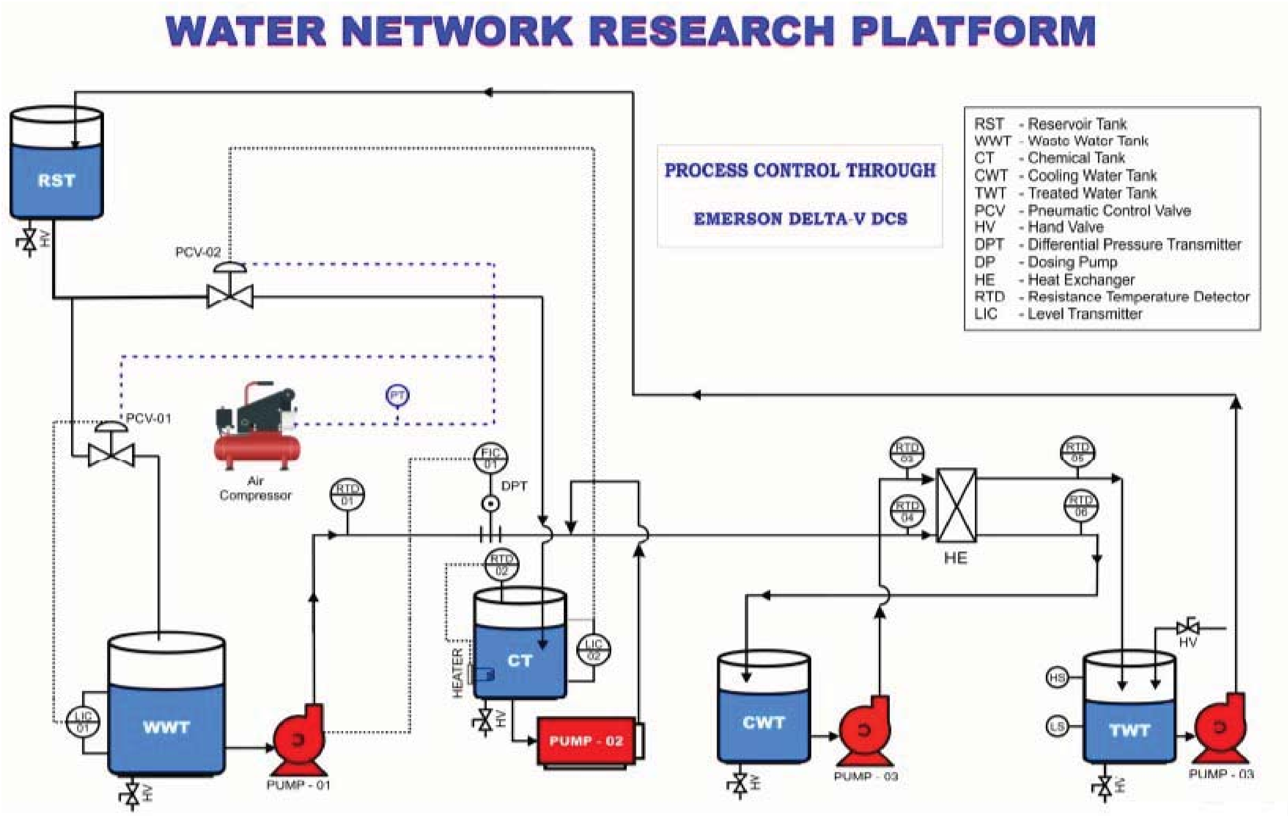

Fig.1 Acid dosing process of waste water treatment plant test bed

temperature which is stored to treated water tank. Here in this whole process sensors and actuators play a vital role. There are flow transmitters, RTD (resistance temperature detector), PT (pressure transmitter), LT (level transmitter) and pneumatic valve.

Flow transmitter is used with pump operated VFD. This flow transmitter is used for measuring the speed so it gives the information about this parameter to DCS controller. RTD used at 5 places because it measures the temperature at different places in the plant. Level transmitter used in WWT and CT because they sense the level of water in the tank and send the information to automation station where based on set point (SP) it will stop pouring water into tank. There are four pumps in water treatment plant (WTP). Pump-01, pump-02 and pump-03 are started manually whereas pump-04 is starts depending upon status of high switch (HS) and low switch (LS). When HS is ON and LS is also ON pump-04 is ON.

II. PID **CONTROLLER**

A PID controller measures the error value as the difference between set-point and measured process variable (PV) & gives the output based on proportional (Gain), integral (Reset) and differential (Rate) terms. For typical values of Kp (proportionality coefficient), Ki (integral coefficient) & Kd These three scaling factors are as SF-ERROR, SF-DELERROR and SF-OUTPUT. First of all these scaling factors are assigned with the 0.2, 2 and 0.2 respectively (they are auto assigned by DeltaV software). But due to slow response an un-accurate output the process variable (output of either sensors or actuator) is not matched with the desired set point.

Authorized licensed use limited to: University at Buffalo Libraries. Downloaded on December 02,2021 at 23:24:45 UTC from IEEE Xplore. Restrictions apply.

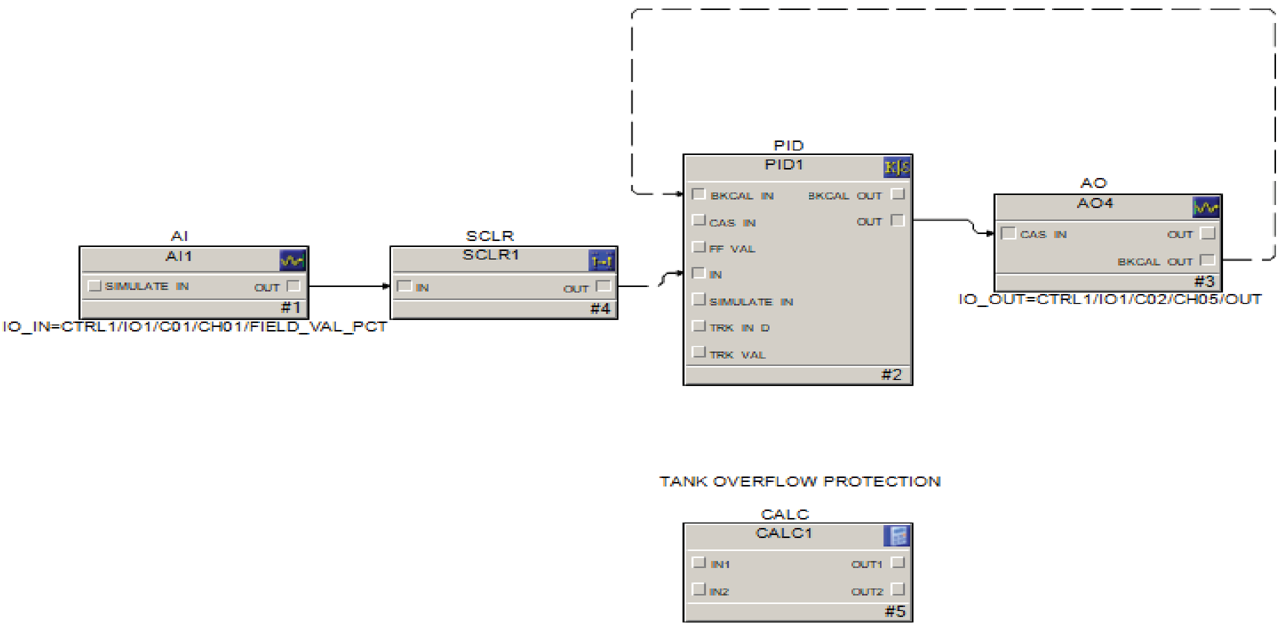

Fig.2 Function Block diagram (FBD) programming of PID controller

In Emerson's DeltaV FBD (functional block diagram) programming language is used. Various modules are made namely, LIC01, LIC02, FIC01, TIC01, PUMP_CWT, PUMP_WWT, PUMP_TWT and WWT. In LIC01, LIC02, FIC01 and TIC01 modules following blocks are used: analog input block, analog output block, SCLR for level adjustment and PID. Then assign input-output blocks to respective channel number.

A FBD of LIC01 using PID is shown in fig.2. Here PID takes input from SCLR and gives output based on the equation

$$u(t) = Kp.e(t) + Ki.\int_0^t e(t')dt' + Kd.(de(t)/dt)$$

A CALC block is used which contains a code for overflow protection. In the WWT plant only the proportional and integral coefficient are used since they both are sufficient for giving desired result.

In the PID, Zeigler Nicolas method is being used. According to it, first keep Ki and Kd equals to zero. Then increase the Kp and observe the behavior of PV (process variable). Then for reaching towards the SP increases the value of Ki. For reducing the high oscillations of PV, Kd value can also be accounted. In our case Kd value was not required hence used PI controller [5]. Parameters adjustment of PID:

1. Mode : Auto
2. Kp(gain) : 1
3. Ki(Reset) :100
4. Kd(Rate) : 0

5. CONTROL-OPTS: "Obey SP lim if Cas or RCas"

III. FLC CONTROLLER AND RESULT ANALYSIS

A fuzzy logic control (FLC) block is advanced substitute for traditional PID block. The algorithms used in FLC is set by the experts in rule base so that FLC is able to give faster & stable response, less settling time and no overshoot. For desired output three scaling factors must be properly set.

These three scaling factors are as SF-ERROR (error), SF-DELERROR (change in error) and SF-OUTPUT (change in control action). The relations among these three variables represent a nonlinear controller. The non-linearity results from a translation of process variables to a fuzzy set (fuzzification), rule inference, and retranslation of fuzzy set to a continuous signal (defuzzification).

The two membership functions for error, change in error and change in output are negative and positive. The membership scaling (S and S∆) and the error value and change in error, respectively, determine the degree of membership.

The change in output membership functions is called singletons. They represent fuzzy sets whose support is a single point with a membership function of one. The membership scaling determines the magnitude of output change for a given error and change in error.

First of all these scaling factors are assigned with the 0.2, 2 and 0.2 respectively (they are auto assigned by DeltaV software).

Authorized licensed use limited to: University at Buffalo Libraries. Downloaded on December 02,2021 at 23:24:45 UTC from IEEE Xplore. Restrictions apply.

GRAPHS OF PID FOR SP, PV AND PID ACTION:

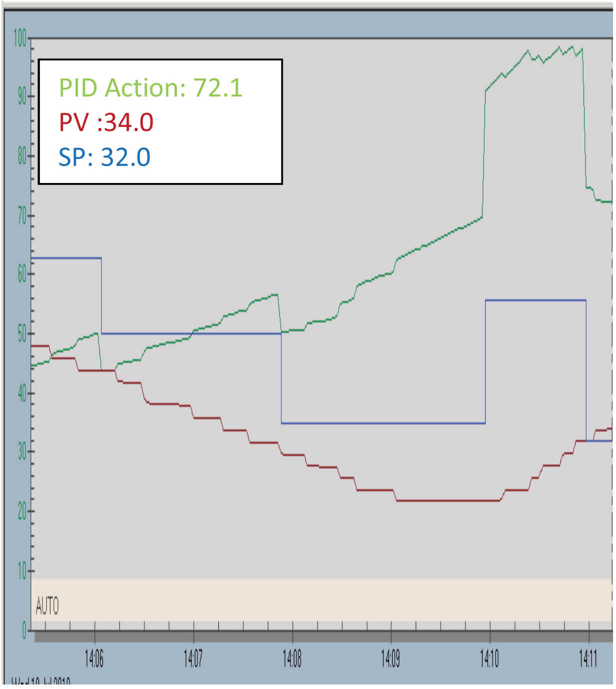

Fig.3 Graph of LIC01 with PID Action

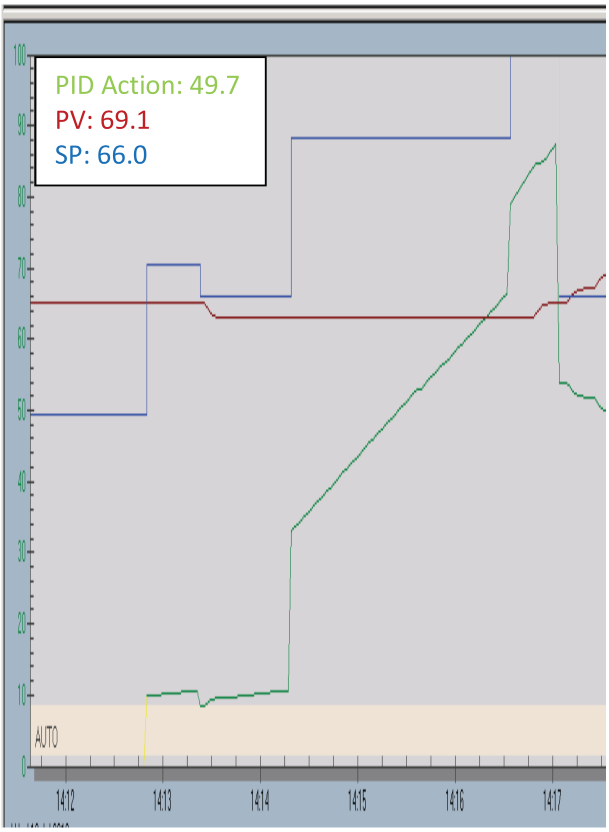

Fig.5 Graph of LIC02 with PID Action

GRAPHS OF FLC FOR SP, PV AND FLC ACTION:

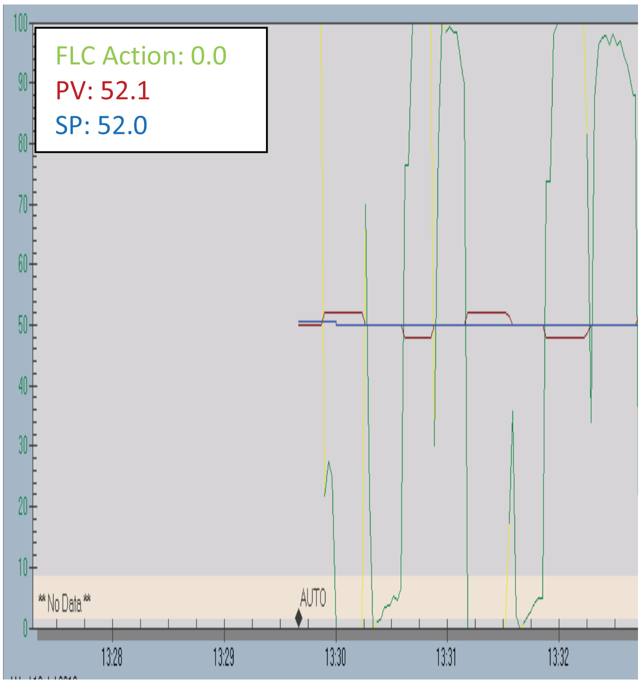

Fig.4 Graph of LIC01 with FLC Action

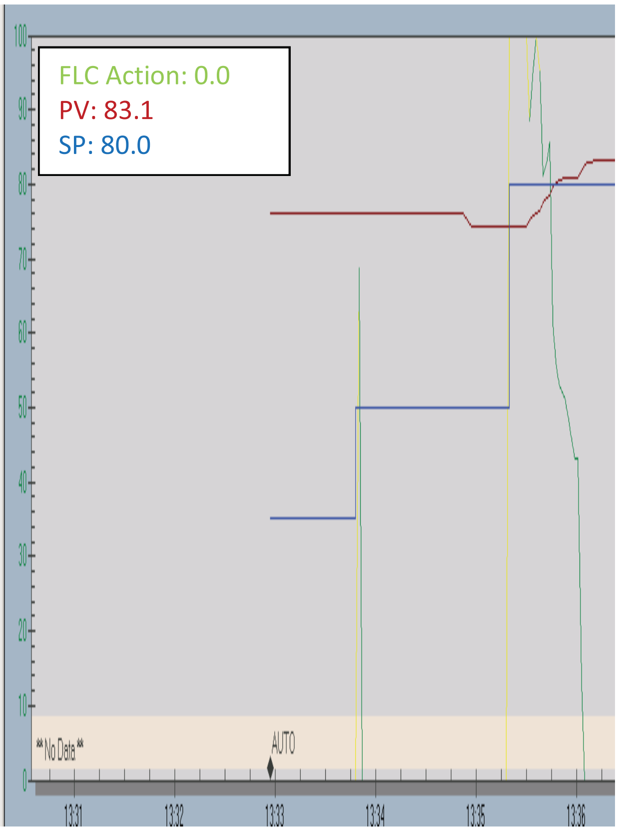

Fig.6 Graph of LIC02 with FLC Action

Authorized licensed use limited to: University at Buffalo Libraries. Downloaded on December 02,2021 at 23:24:45 UTC from IEEE Xplore. Restrictions apply.

Fig.7 Graph of FIC01 with PID Action

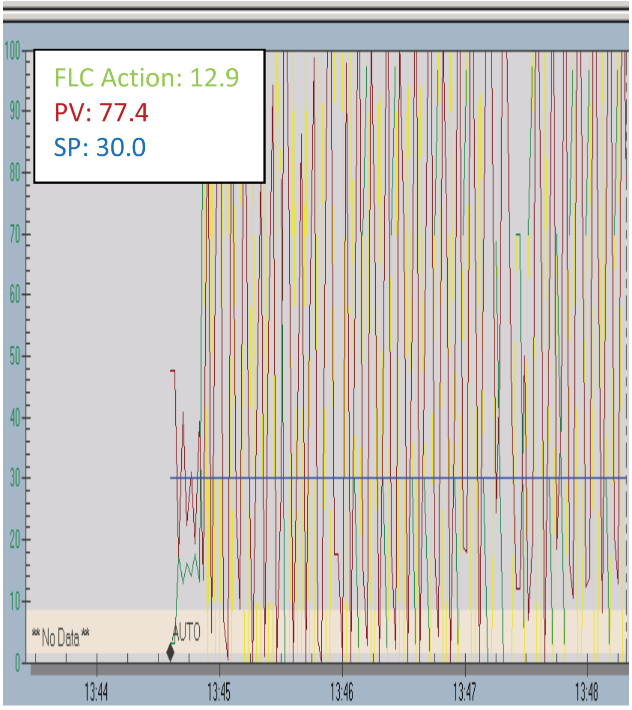

Fig.8 Graph of FIC01 with FLC Action

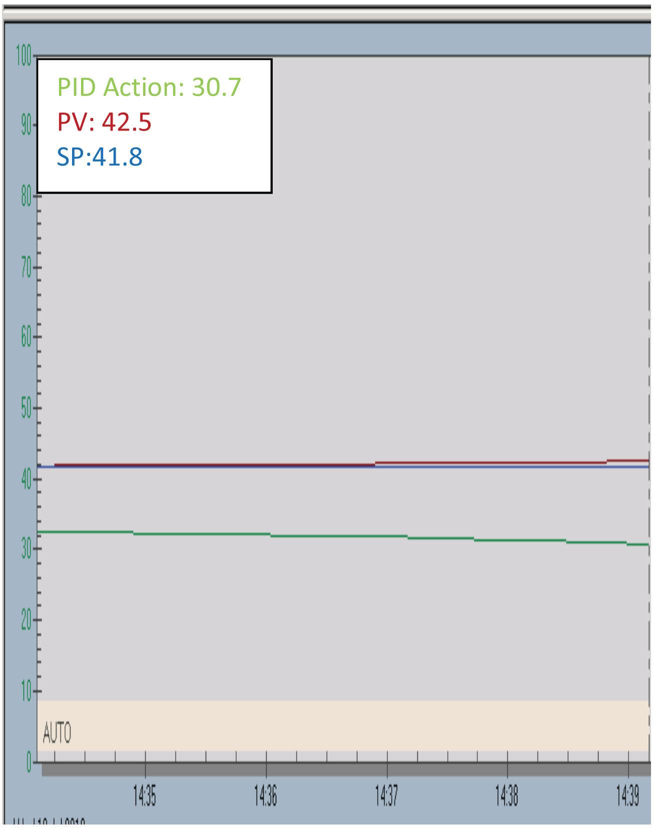

Fig.9 Graph of TIC01 with PID Action

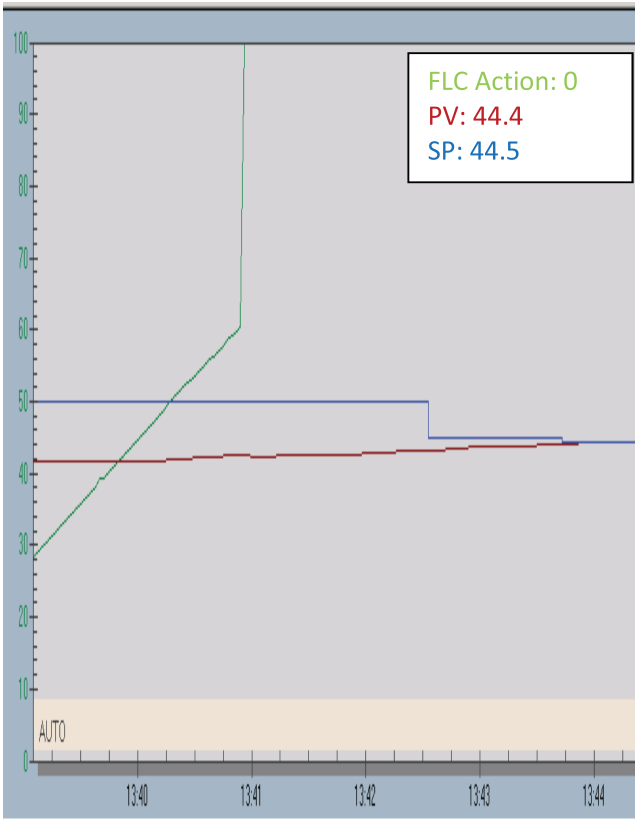

Fig.10 Graph of TIC01with FLC Action

Authorized licensed use limited to: University at Buffalo Libraries. Downloaded on December 02,2021 at 23:24:45 UTC from IEEE Xplore. Restrictions apply.

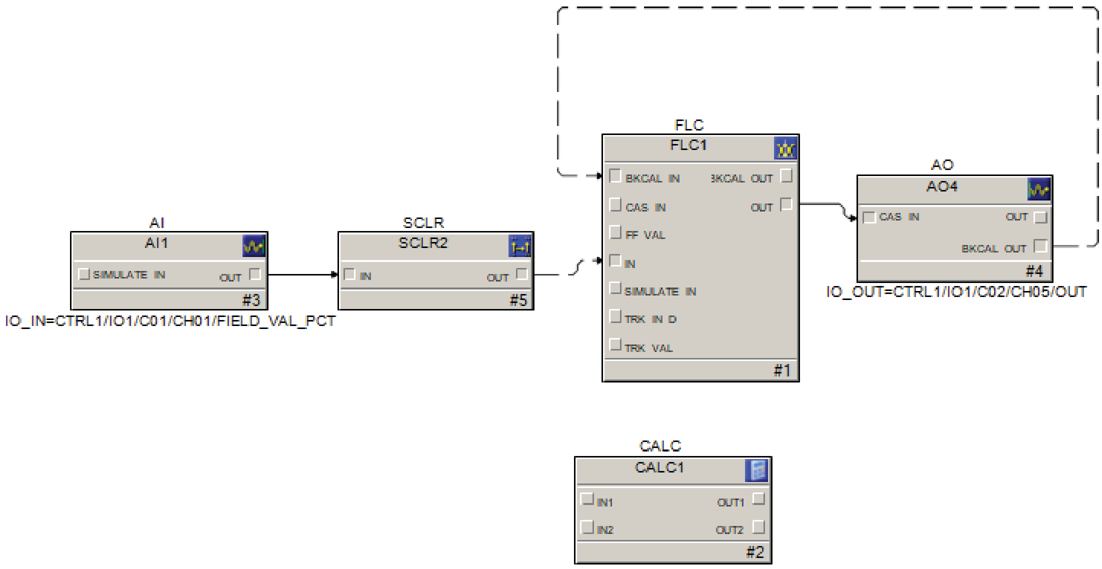

Fig.11 Function Block diagram (FBD) programming of FLC controller

But due to slow response an un-accurate output the process variable (output of either sensors or actuator) is not matched with the desired set point.

By keep on increasing the values of scaling factors the control action start to approaching the desired set point. So for a perfect match the values of these three scaling factors are shown in below parameter section.

In the water treatment plant after the replacement of PID with FLC due to some reasons which are described above. There are four FLC controllers being used. FLC is used in TIC01, LIC01, LIC02 and FIC01.Atypical FBD block using FLC is shown in fig. 11[6], [7].

Parameter adjustment of FLC:

1. Mode: Auto
2. CONTROL-OPTS: "Obey SP lim if Casor RCas"
3. SF_ERROR:2
4. SF-DELERROR: 20
5. SF-OUTPUT: 70

IV. CONCLUSION

The traditional PID controller is compared with modern fuzzy logic controller for the acid dosing process of water treatment plant. As graphs obtained from actual test bed plant it can be seen in Fig.3 - Fig.10 that fuzzy logic Controller gives better output results than PID as the settling time and overshoot is less.

REFERENCE

[1] Gustaf Olsson, M. Nielsen, Zhiguo Yuan, Anders Lynggaard-Jensen, J.-P.Steyer, Instrumentation, Control and Automation in Wastewater Systems, 2005, IWA Publishing.

[2] Surekha Bhanot, Processs Control: Principles and Applications, 2008, Oxford University Press.

[3] Chun-Tang Chao, Nana Sutarna, Juing-Shian Chiou and Chi-Jo Wang, Equivalence between Fuzzy PID Controllers and Conventional PID Controllers, 2017, Applied Sciences.

[4] Eshani Mishra, Sachin Tiwari Comparative Analysis of Fuzzy Logic and PI Controller Based Electronic Load Controller for Self-Excited Induction Generator, 2017, Advances in Electrical Engineering Volume 2017.

[5] Jens Graf, PID Control: Ziegler-nichols Tuning, 2013, Createspace Independent Publishing Platform.

[6] Guanrong Chen, Trung tat Pham, Introduction to Fuzzy Sets, Fuzzy Logic and Fuzzy Control Systems, 2001, CRC Press.

[7] Timothy J Ross, Fuzzy Logic with Engineering Application, 2011.

Authorized licensed use limited to: University at Buffalo Libraries. Downloaded on December 02,2021 at 23:24:45 UTC from IEEE Xplore. Restrictions apply.