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Design and Simulation of ANFIS-PI Controller for Spherical Tank System

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ABSTRACT

Control of the liquid level in the spherical tank is one of the major problems in the process industry. This is due to its high nonlinearity and long dead time. The level of the spherical tank can be controlled using a Proportional-Integral (PI) controller. In this paper, a model of a spherical tank with a self-tuning Adaptive Neuro-Fuzzy Inference System (ANFIS) controller is implemented using MATLAB Simulink software to obtain the desired output levels. Simulation results showed that the ANFIS-PI controller improved the performance of the spherical tank over the conventional PI controller using the Direct Synthesis method.

Keywords: *ANFIS, Direct synthesis method, MATLAB, Nonlinear, Spherical tank.*

I. INTRODUCTION

Chemical processes expose many challenging control problems due to nonlinear dynamic behaviour, such as uncertainty, time-variant properties, and constraints on a manipulated variable. In a spherical tank area of the cross-section keeps varying with the change in height of the tank. Controlling the level in a spherical tank is difficult because the change in shape gives rise to non-linearity. To overcome the above difficulties, the liquid level in the spherical system is controlled by various techniques. A Proportional-Integral controller, which works on a control loop feedback mechanism, is widely used in industrial control systems. The PI controller continues to calculate an error value as the difference between the desired set point (SP) and a measured process variable (PV) and applies a correction based on proportional and integral terms. Normally, a PI controller is used to control the liquid level of the spherical tank. The Proportion-Integral controllers have difficulties in implementing control action in the presence of non-linearity. Conventional PI controller does not have satisfactory response, when the behavior of process changes and introduction of large disturbance. The Adaptive Neuro-Fuzzy Inference System (ANFIS) PI controller is implemented to overcome the PI controller's drawback. It has a self-tuning ability that tunes the PI controller based on ANFIS rules that are built into the ANFIS designer. This intelligent system is a kind of artificial neural network that is based on the Takagi–Sugeno fuzzy inference system. Since it integrates both neural networks and fuzzy logic principles, it has the potential to capture the benefits of both in a single framework. In this paper using two controllers, such as Direct Synthesis Method (DSM-PI) and Adaptive Neuro-Fuzzy Inference System (ANFIS).These two controllers are implemented to control the liquid level of the spherical tank. The results are compared using the time domain parameters such as settling time, rise time and overshoot.

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II. MATHEMATICAL MODELLING

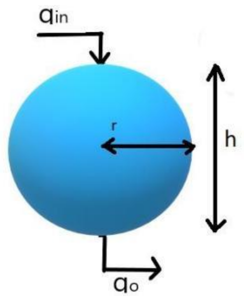

Figure1 Spherical tank model

The model of the spherical tank level process diagram is shown in Figure 1. The differential equation which is to represent the above-mentioned model is,

$\frac{dV}{dt} = \rho_1 q - \rho_2 q_0$

V= volume of the spherical tank L

ρ = Density of the liquid in the stream Kg/Lt

ρ_1 = Density of the liquid in the inlet stream Kg/Lt

ρ_2= Density of the liquid in the outlet stream Kg/Lt

On solving,

$$\frac{dh}{dt} = \frac{q_i}{\frac{\pi h_s^2}{2}} - \frac{c\sqrt{h}}{\frac{\pi}{2}h_s^2} \quad (1)$$

$$\frac{H(s)}{Q_{in}(s)} = \frac{\frac{2\sqrt{h_s}}{c}}{1+\frac{2\sqrt{h_s}}{c}\frac{\pi h_s^2}{2}s}$$

$$\frac{H(s)}{Q_{in}(s)} = \frac{R_t}{\tau_s+1} \quad (2)$$

The differential equation of the spherical is given in equation (1) and transfer function in equation (2),[11].

The transfer function for set point 10 cm is $\frac{H(s)}{Q(s)} = \frac{0.9897}{155.38s+1}$

The transfer function for set point 15 cm is $\frac{H(s)}{Q(s)} = \frac{1.213}{428.70s+1}$

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III. DESIGN OF CONTROLLERS

(i) Direct Synthesis Method

In the Direct Synthesis (DS) method, the controller design is based on a process model and a desired closed-loop transfer function. The latter is usually specified for set-point changes and responses to disturbances can also be utilized. Although these feedback controllers do not always have a PID structure, the DS method does produce PI or PID controllers for common process models. The block diagram for feedback control system is given in figure 2. The equation of the controller for the first-order process is given below

$$\tilde{G} = \frac{K_p}{\tau_p s + 1}.$$

$$G_c = \frac{1}{\frac{K_p}{\tau_p s+1}} \cdot \frac{1}{\tau_c s} = \frac{\tau_p s+1}{K_p \tau_c s} = \frac{\tau_p}{K_p \tau_c}\left(1 + \frac{1}{\tau_p s}\right)$$

$$K_c = \frac{\tau_p}{K_p \tau_c} \text{ and } \tau_I = \tau_p$$

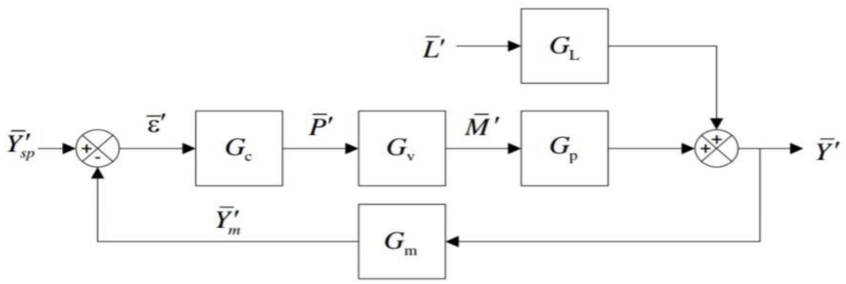

Figure 2 Block diagram for the feedback control system.

(ii) Adaptive Neuro-Fuzzy Inference System

An Adaptive Neuro-Fuzzy Inference System or Adaptive Network-Based Fuzzy Inference System (ANFIS) is a kind of artificial neural network that is based on the Takagi–Sugeno fuzzy inference system. Since it integrates both neural networks and fuzzy logic principles, it has potential to capture the benefits of both in a single framework. Its inference system corresponds to a set of fuzzy IF–THEN rules that have learning capability to approximate nonlinear functions. This principle is to obtain the proportional and integral gains of PI controller.The error and change in error is taken as input to the controller. Error is divided into 5 triangular membership function and change in error into 4 membership function. 20 rules are formed and these rules are used to get the optimum output which gives k_p and k_i values of the ANFIS-PI controller. The structure of ANFIS controller is shown in figure 3.

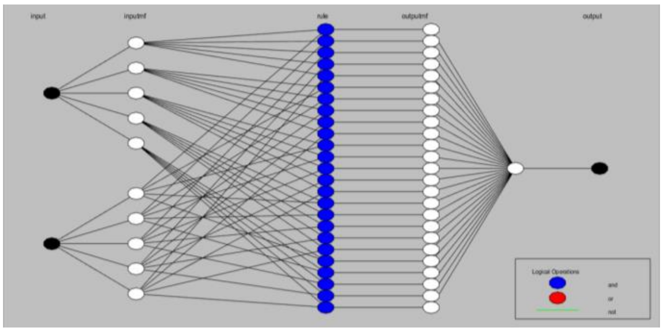

Figure 3 Layers of ANFIS controller

IV. SIMULATION AND RESULT DISCUSSION

Using the fuzzy logic, the training data for the ANFIS-PI controller is obtained. It is utilised to get the K_p and K_i values of the PI controller. The training for k_p and k_i is shown in figure 4 and figure 5.

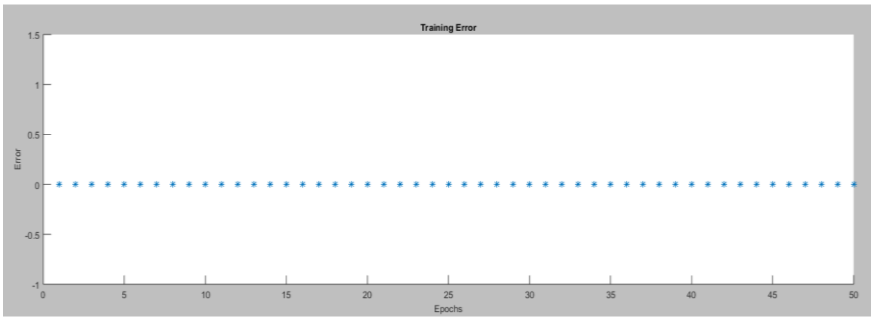

Figure.4 Error after training of K_p

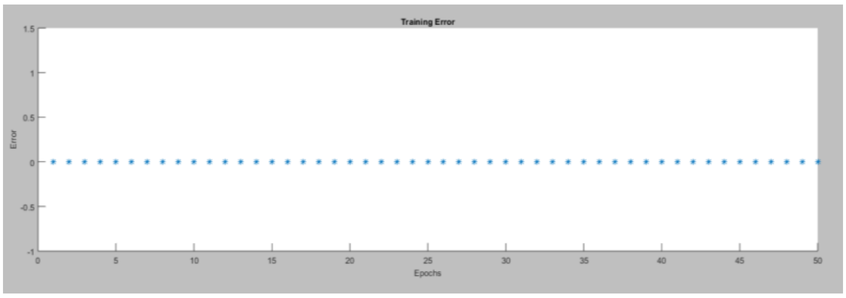

Figure5. Error after training of K_i

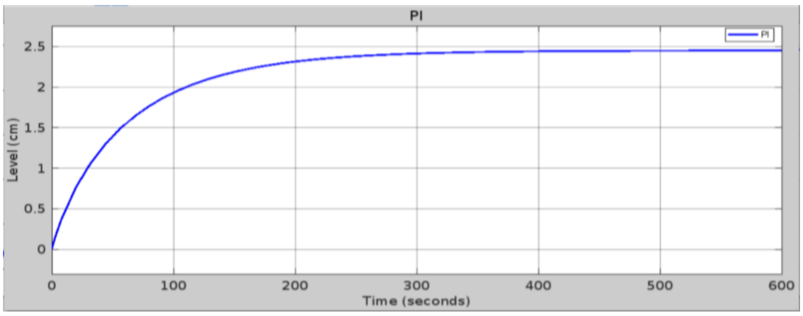

Figure 6 Open loop response for a set point of 10 cm

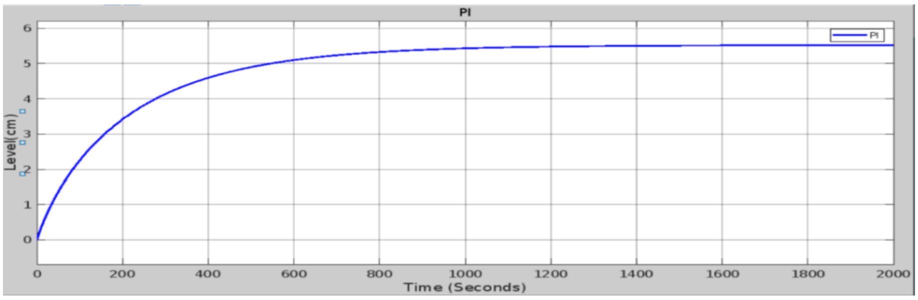

Figure 7 Open loop response for a set point of 15 cm

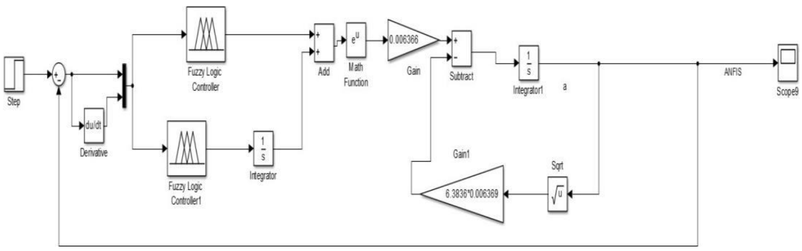

Figure 8 Simulation diagram of close loop system with ANFIS – PI controller

Table 1 PI controller value

Controller	Level (cm)	Kp	Ki
DSM-PI	10	6.2	1.5
	15	4.7	2
ANFIS-PI	10	$6.9 * 10^{-3}$	3.005
	15	$0.13*10^{-3}$	3.209

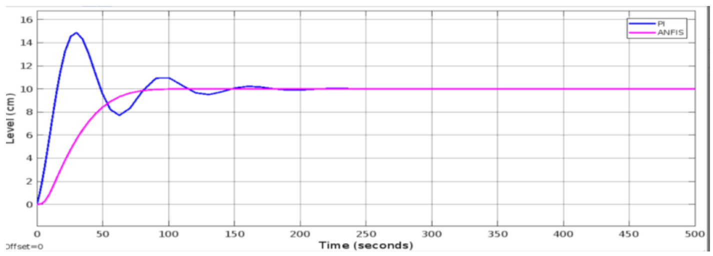

Figure 9 Comparison of DSM-PI and ANFIS-PI controller for a set point of 10 cm

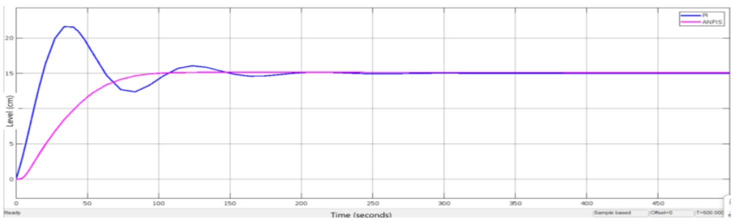

Figure10 Comparison of DSM-PI and ANFIS-PI controller for a set point of 15 cm

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The performance of DSM-PI and ANFIS-PI controller is compared for the set point at 10 cm and 15 cm.Initially, Direct Synthesis Method based PI controller is used. This controller has a large overshoot and takes a long time to settle. Whereas, when the ANFIS-PI controller is used. The above mentioned disadvantage has been overcome as shown in fig 8 and 9.

Table 2 Performance analysis of controllers

Specification	Set Point (cm)	DSM-PI	ANFIS-PI
Rise time (ses)	10	11.6	46.79
	15	14.20	55.84
%Overshoot	10	46.32	0.05
	15	44.20	0.50
Settling time(sec)	10	300	115
	15	380	130

V. CONCLUSION

The performance of both controllers is evaluated on various parameters. The results show that the response with the DSM-PI controller has a large overshoot and it takes a long time to settle. The ANFIS-PI controller significantly reduces the settling time and eliminates the overshoot. Thus the ANFIS-PI controller gives better results than the DSM-PI controller.

REFERENCES

[1] G.S G.Sakthivel, T.S.Anandhi, S.P.Natarajan, “Design of Fuzzy Logic Controller for a Spherical tank system and its Real time implementation”, International Journal of Engineering Research and Applications (IJERA)ISSN: 2248-9622,Vol. 1, Issue 3, pp.934-940,

[2] Ajith B.Singh, J.Mownika, S.K.Apoorvaa, Gowtham Bal :Subramanian, P.Manju, G.S.Monishaa, “Investigation of Intelligent Controller for Nonlinear Spherical Tank system”, ISSN, Vol.9,No.2, 2021.

[3] Boobalan S, Lakshmi K, Gobhinath S, “Mathematical Modelling and Simulation of Nonlinear PID controller for Spherical Tank Level Control in oil and Gas Industry”, IJITEE, Vol. 8,Issue 7, 2019

[4] Iwan Rohman Setiawan “Characterization of Simulator for Water Level Control in the Tank – Single Loop”, International Journal of Engineering and Techniques, Vol. 4, Issue 1, 2018.

[5] T.Gowtham, Dr.M.Balaji, “Control of Non Linear Spherical Tank Process with PI-PID Controller-A Review”, Journal of Engineering Research and Application”, Vol.8, Issue 9 (Part – III), pp28-34, Sep 2018.

[6] Boo Poonguzhali, R. Vinodha and N. Seetharama, “Neural Tuned Fuzzy Logic Controller for Spherical Tank”, Process Journal of Engineering Research & Technology (IJERT),ISSN 2278-0181,Vol. 3 Issue 2, February – 2016.

[7] Bharathi, C.Selvakumar, A.Kalpana , “Model Based Controller Design for a Spherical Tank”, IOSR Journal of Electrical and Electronics Engineering , Vol.9, Issue 2 Ver.VI, 2014.

[8] Ms.Dighe Y.N, Prof. Kadu C.B, and Prof. Parvat B.J, "Direct Synthesis Approach for Design of PID Controller", IJAIEM, Vol3, Issue 5, 2014.

[9] Ben Joe Raj, "Fuzzy Logic Based PID Controller for a Non Linear Spherical Tank System", International Journal of Engineering Research & Technology (IJERT), ISSN: 2227-0181, Vol. 3 Issue 2, February – 2014.

[10] K.Hari Krishna, J Satheesh Kumar and Mahaboob Shaik "Design and Development of Model Based Controller for Spherical Tank", International Journal of Current Engineering and Technology, Vol.2, No.4, pp. 374-376, ISSNO 2277-4106, 2012.