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Three Tank Interacting System Level Control using Modern AI Techniques

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Abstract- **A multi tank level control system has an example of interacting and non-interacting system. In this system, we have considered three tanks each having equal cross section area and each tank can be assumed as a first order system which are connected in interacting and various non-interacting mode. Control of the level in the tank and flow in between them is basic problem in process control industries almost all the chemical industries are connected in cascade for storage of liquid and for other chemical processes. all the tank have their own manipulated variable to control liquid level inside the tank so in this section we are analyze the response of various type of tank, like conical, rectangular etc. the response of these tank which are connected in interacting and non interacting mode are observed with applying step input and response these system is improved by designing various type of controller like feedback controller and feed-forward controller. Effect of interaction is also observed and the effect of this interaction is minimized by designing adding A.I techniques like fuzzy and ANN.**

Keywords- ANN, Fuzzy, PID Controller, Tank.

1. Introduction:

Multi tank systems are widely used in chemical and petroleum industries so as to control the liquid level in the tank. It is the challenging task as it may affect both pressure and flow of the process so it is important to maintain level at set point. In this project the transfer function of the three tank system has been formulated. Three tank system is shown in Fig. 1.

Various type of feedback controller can be used to control the liquid level in the tank but biggest problem is when disturbance come in to the picture. To nullify the effect of the disturbance we have to implement feed forward controller. To maintain liquid level at desired set point combination of feedback and feed forward-feedback controller is used.

2 Related Work:

Control of liquid level in any process control is challenging task. There are many different connection of tanks possible in the plant like Interacting and Non-Interacting. Many type of disturbances are possible which can affect the performance of the system. designing of controller for these type of process is challenging task in process control industries

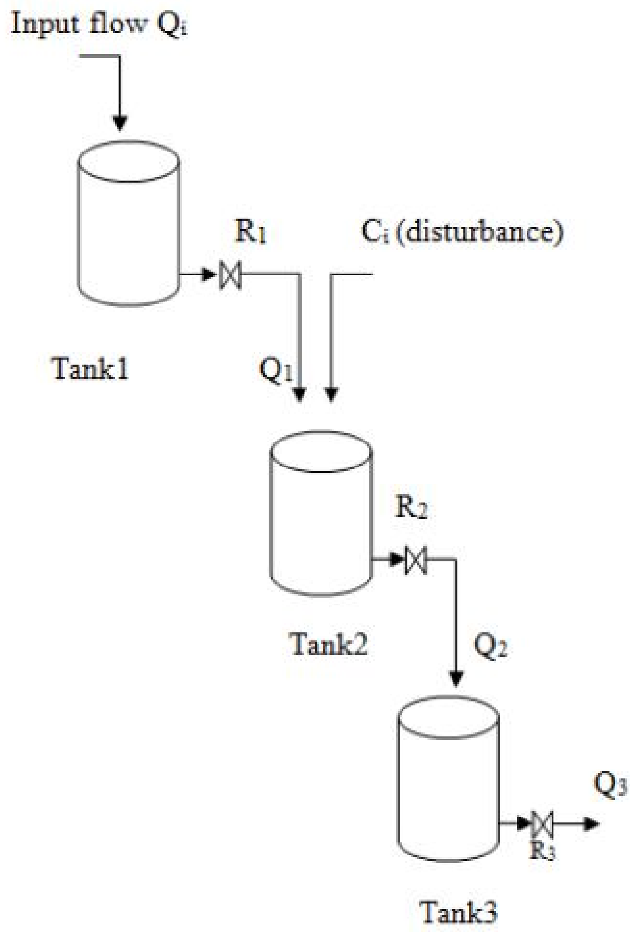

Fig. 1. Three tank Non-Interacting system

Juan J. Gude and Evaristo Kahoraho, (2010) [7], according to them the Ziegler-Nichols tuning rules have been very influential and have been used extensively in process industry. This work presents an extension of the modified Ziegler-Nichols tuning rules for fractional PI controllers. The design method consists on minimizing a frequency objective function subject to a constraint on the maximum sensitivity function MS. In this work it is also demonstrated that substantially better performance can be obtained using PI instead of PI controllers. An interpretation of these tuning rules as methods where one point of the Nyquist curve is positioned in a desired point is also given. These tuning rules are compared with other tuning rules and shown to give good results, especially when simplicity, performance and robustness are emphasized. This work presents an extension of the Modified Ziegler-Nichols tuning rules for PI controllers. Good results are obtained in comparison with other tuning rules. Future investigations should rely on extending these rules for different values of and for PID controllers.

This work presented by **V.R.Ravi et. al., (2011),** [2] control of non linear Two Tank Conical Interacting System (TTCIS) using Gain Scheduling Adaptive Controller (GSAC). This TTCIS is considered as two tank benchmark setup for interacting non linear systems. The transfer function of TTCIS was derived and the relationship between TTCIS parameters and PI controller parameters were derived for implementing GSAC for TTCIS. Two cases namely multiple linear models of TTCIS with as many PI controllers and nonlinear TTCIS model with GSAC were considered. The Genetic Algorithm (GA) was used to obtain the optimal PI control settings in first case. The experimental setup for TTCIS was designed and fabricated. The simulation and experimental studies were carried out for all the two cases on a benchmark TTCIS. The advantages of Gain Scheduling Adaptive Controller over GA tuned multi PI controllers were highlighted. They concluded that the Gain Scheduling Adaptive Controller is best suitable for regulatory operations and variation in process parameter for the TTCIS process.

The interactions between input/output variables are a common phenomenon and the main obstacle encountered in the design of multi-loop controllers for interacting multivariable processes. In this work, a method for controlling multivariable processes is presented by **V. R. Ravi et. al. (2011)**. [4] The controller design is divided into two parts: firstly, a decoupling matrix is designed in order to minimize the interaction effects. Then, the controller design is obtained for the process + decoupler block. The aim is to meet the design specifications for each loop independently. This method for multivariable decoupling and multiloop PID controller is applied to Two Tank Conical Interacting System (TTCIS). This TTCIS is considered as two tank benchmark problem used by many researchers. Simulation results and experimental results with TTCIS are provided to demonstrate the effectiveness and practicality of the proposed method.

R. Ravi et. al. (2012) [8] according to them Model predictive control (MPC) has become the leading form of advanced multivariable control in the chemical process industry. The objective of this work is to introduce a gain scheduling control strategy for multivariable MPc. The method of approach is to design multiple linear MPC controllers. This strategy maintains performance of multiple linear MPC controllers over a wide range of operating levels. One important contribution is that the strategy combines several multiple linear MPC controllers, each with their own linear state space model describing process dynamics at a specific level of operation. One of the linear MPC controller output is selected as gain scheduling adaptive controller's output based on the current value of the measured process variable. The tuning parameters for the MPC controller are obtained u sing real coded Genetic Algorithm (GA). The capabilities of the gain scheduling adaptive (GSA) control strategy for MPC controller are investigated on Two Conical Tank Interacting Level System (TCTILS) through computer simulation.

The dynamic behaviour of two tank interacting system was studied by the introduction of a step change in the manipulated variable (flow rate) and measuring the controlled variable by development of the suitable mathematical model of the system. This work described by **Parag Joshi (2013)** [10], how the effect of the interaction of this interacting system is minimized by the design of the suitable de-coupler for the system and also includes the analysis of the interacting loops between the controlled variable that is liquid level of both tank and manipulated variable that is inlet flow rate. Generally in two tank interacting system there is no inlet flow rate for tank two , but this work simplifies the industrial interaction problem where different tanks has different inlet and this is done by the help of relative gain array method. The result exemplifies that the gain of each loop is reduced approximately half when the opposite loop is closed and the gain of other loop changes the sign when the opposite loop is closed. Thus the decoupling is the most appropriate method for achieving minimal interaction and is most efficient method.

3. Methodology:

3.1 Artificial Neural Networks (ANNs):

ANN concepts are based on the present understanding of the biological nervous systems. An ANN is “a massively parallel-distributed information processing system that has certain performance characteristics resembling biological neural networks of the human brain” [3]. Parallel processing elements of network layers is called neurons. In most of the networks, the input layer receives the input variables from the problem data. This consists of all variables that can influence the output. The output layer consists of values predicted by the network and thus represents model output. Between the input layer and output layer there may be one or more hidden layer. The neurons in each layer are connected to the neurons in a proceeding layer by a weight ‘w’, which can be adjusted during training. The networks are organized by training methods, which greatly simplifies the development of specific applications. Fig 2 illustrates a three-layer neural network consisting of four neurons in input layer, four neurons in hidden layer and two neurons in output layer, with the interconnection weights between layers of neurons.

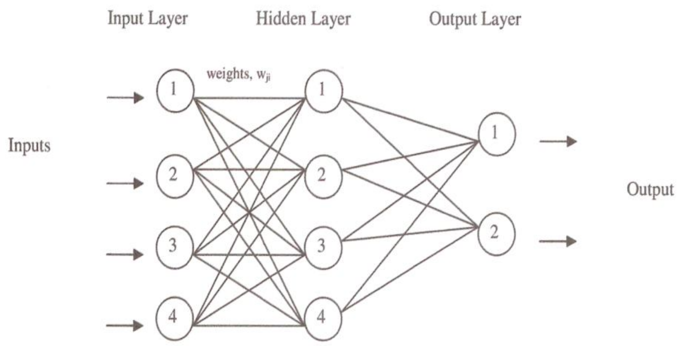

Fig. 2. A three layer Neural Network Configuration

Back-propagation is the most popular algorithm for training ANNs. The back-propagation algorithm gives a recommendation for changing the weights, wji, in any feedforward network to learn a training set of input-output pairs. It is a supervised learning method in which an output error is fed back through the network, shifting correlation weights so as to minimize the error between the network output and the target output.

3.2 Fuzzy Logic:

"In almost every case you can build the same product without fuzzy logic, but fuzzy is faster and cheaper . . .". [1]
Fuzzy logic is a superset of conventional or classic logic that has been extended to handle the concept of partial truth (truth values between *completely true* and *completely false*). Fuzzy logic is discussed in detail in. Fuzzy logic concerns the relative importance of precision. How important is it to be exactly correct when a rough answer will do? Fuzzy logic balances significance and precision (see Fig 3), something that humans have been managing for a very long time.

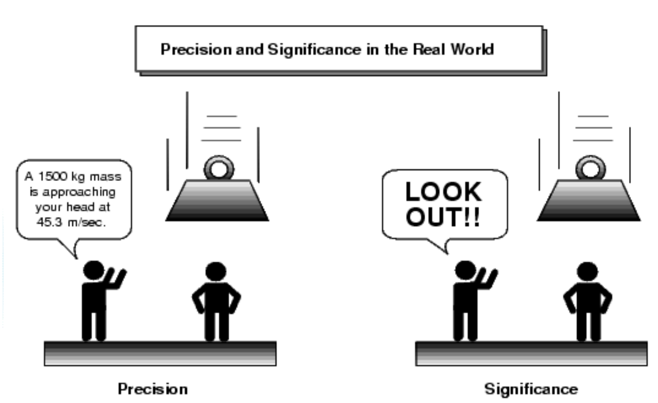

Fig. 3. Precision versus significance (Source Matlab, 2011)

Fuzzy logic is a convenient way to map an input space to an output space, thereby capturing the knowledge of experts. For example, a user states how good the service was at a restaurant, and fuzzy logic tells the user what the tip should be.

3.3 Proposed Work:

3.3.1 PID Controller of Three Tank Interacting System with Disturbance:

We discussed about the results obtained for three tank interacting system level control using POD, fuzzy and ANN controller. We have developed the simulation model using transfer function equations of three tank interacting system for tank level w.r.t to step input (transfer function 1) and w.r.t to disturbance (transfer function 2) and we designed MATLAB/Simulink model of 2 inputs 1 output MIMO system as shown in fig 4.

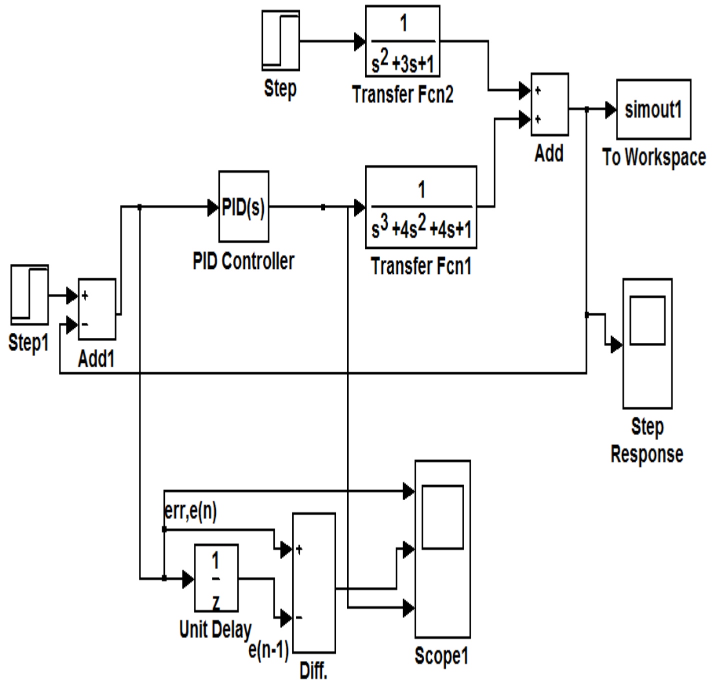

Fig. 4. PID Controller based Level Control of Three Tank Interacting System with Disturbance.

3.3.2. Fuzzy Controller of Three Tank Interacting System with Disturbance:

For improving the performance of controller for three tank interacting system with disturbance we have applied a fuzzy controller by observing the value of error (e) and change in error (Δe) values at the input end of the PID controller. From the data analysis the fuzzy inference system (fis) input are range is decided to replace the PID by fuzzy controller. The FIS system based controller for three tank interacting system with disturbance is shown in Fig 5.

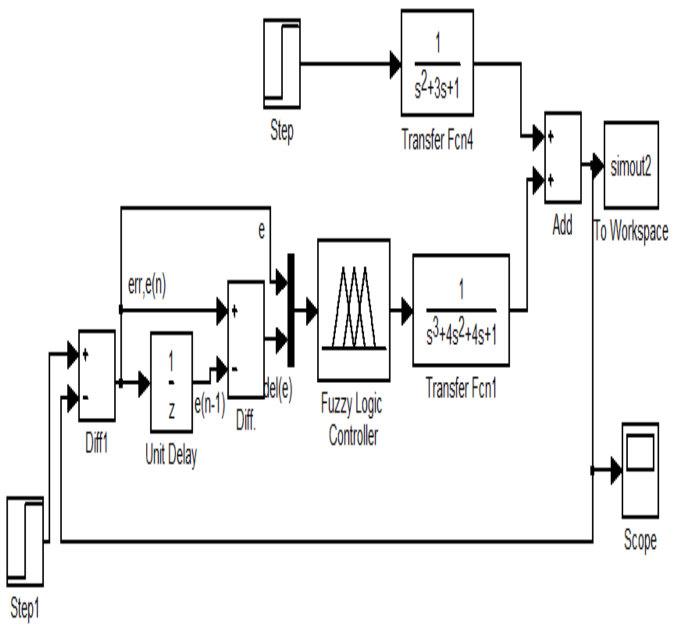

Fig. 5. Fuzzy Controller based Level Control of Three Tank Interacting System with Disturbance.

4. Result and Discussion:

In the fig 4 step 1 is the fluid flow and step is the disturbance the controller here used is the PID controller for controlling the fluid level of the of three tank interacting system. The PID controller block parameter specification are shown in fig 6.It shows that the tuned PID controller as the values of Kp= 1.0457323598035 , Ki= 0.387294740392378 and Kd= -0.0249261857376972.

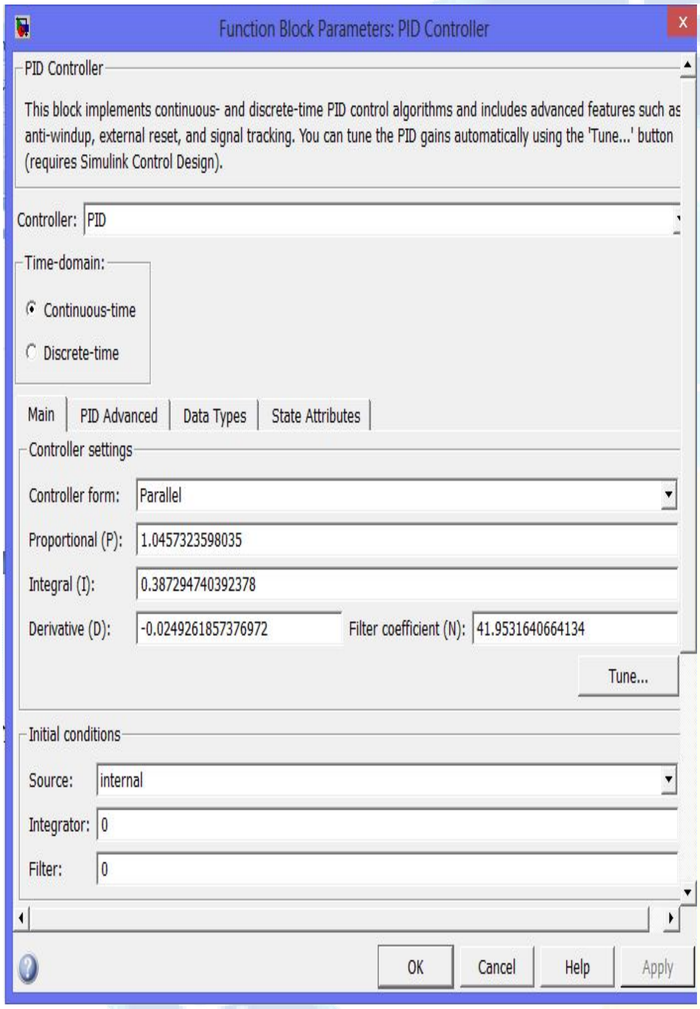

Fig 6. Block Parameters of Tuned PID Controller of Three Tank Interacting System with Disturbance.

The simulink model of PID controlled system is run for 40 seconds to obtain the step response and the scope 1 is used to observe the error change in error and controller output. Where error is shown as e(n),change in error is e(n)-e(n-1).The step response of three tank interacting system with disturbance is shown in figure 4.In this step response the peak value of the step response is 1.3202 at the time of at the 6.0816 second and the rise time at which step response first time reached at the 90 percent of the step input is observed as t_{rise}= 3.3930sec. Hence it can be observed that the system is capable of controlling the fluid level with stable response at a peak overshoot of 32% at a rise time taken to reach the 90% of final response in 3.4 seconds (approx.) with steady state error of zero.

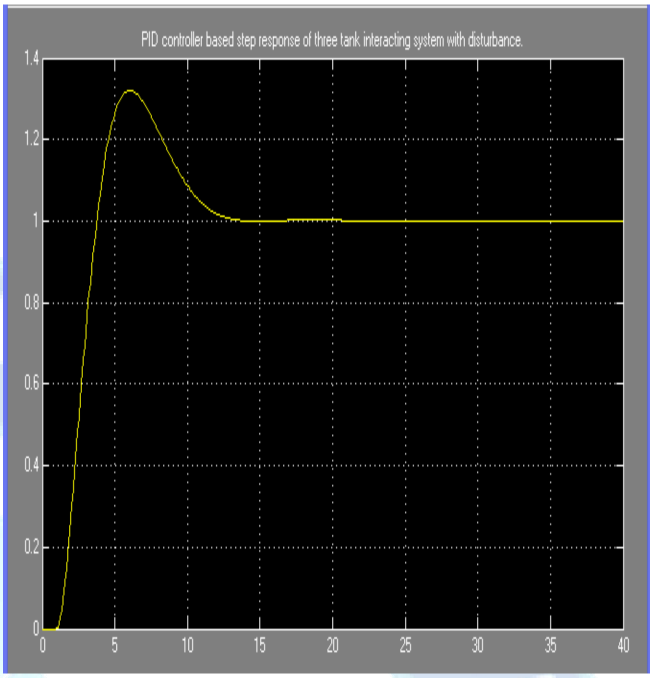

Fig. 7. PID Controller based Step Response of Three Tank Interacting System with Disturbance.

Since the FIS system has two inputs and one output so the output is plotted in 3D plot of the fuzzy rules in the fig 8.In this surface view the x-axis is delerr and y-axis is err and z-axis is controller output varying from -2 to +2 for different combinations of both input values.

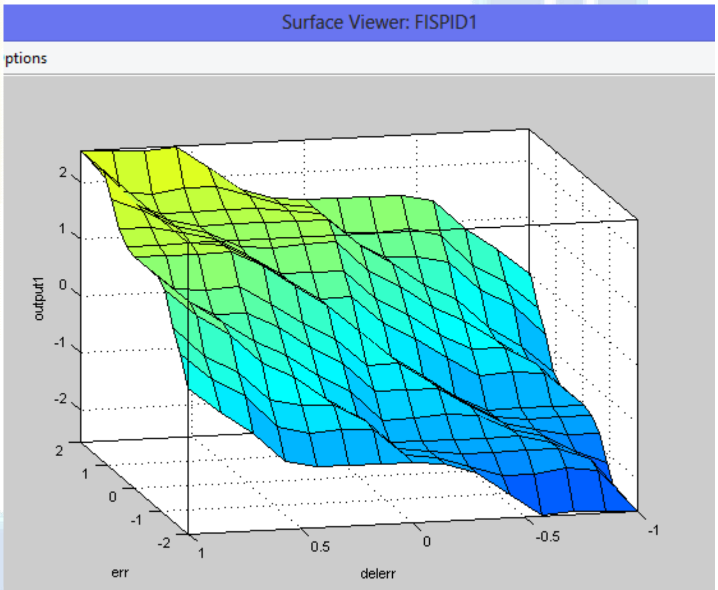

Fig. 8. Rule Editor based Surface View for the Fuzzy Rules for the FIS Controller.

The above described system when connected with the three interacting tank system the step response of the observed system is produced for the simulink model as shown in figure 5. The simulink model of fuzzy controlled system is run for 40 seconds to obtain the step response and the scope 1 is used to observe the error change in error and controller output. Where error is shown as e(n),change in error is e(n)-

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e(n-1).The step response of three tank interacting system with disturbance is shown in figure 14.In this step response the peak value of the step response is 1.0973 at the time of at time 5.0750second and the rise time at which step response first time reached at the 90 percent of the step input is observed as t_{rise}= 3.4252sec. Hence it can be observed that the system is capable of controlling the fluid level with stable response at a peak overshoot of 9% at a rise time taken to reach the 90% of final response in 3.4 seconds (approx.) with steady state error of zero.

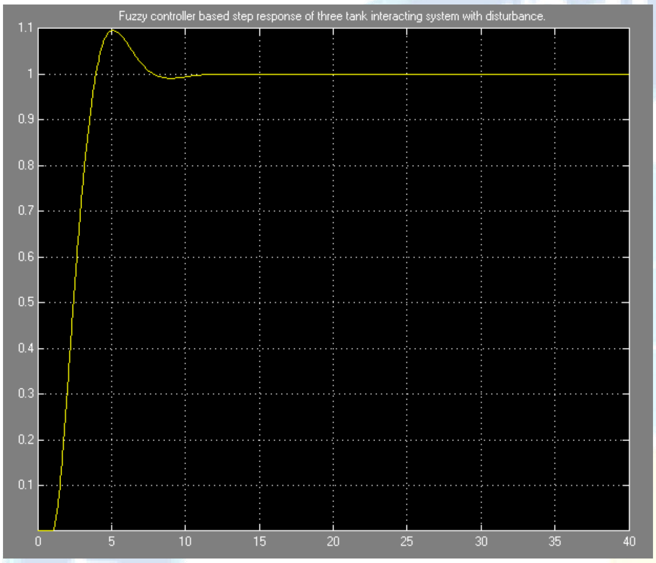

Fig. 9. Fuzzy Controller Based Step Response of Three Tank Interacting System with Disturbance.

5. Conclusion:

From the comparative analysis of all it has been observed that the PID controller is capable of controlling the step response but it gives a peak overshoot of 30% at peak time of 6 sec hence ii can be concluded that PID controller is slow and gives high peak values. The speed and peak value both are improved by using the fuzzy controller the peak overshoot is reduced to 9% and the peak time become 5.07 seconds but the rise time of the both systems are 3.4 seconds hence there is no improvement are found in system speed for PID and fuzzy controller in terms of rise time. The designed ANN controller consist of 20 neurons and the MSE value of 0.005 which shows that the ANN is very efficient to evaluate the controller output for given error and change in srror values and it justified that ANN can be replaced by FUZZY and PID controller. On using the ANN the peak overshoot become 20% at the peak time of 4.4 seconds and rise time of 3 seconds hence it proves that the fastest controller is ANN based but at the sacrifice of 20% peak overshoot. The execution time of the simulink model are recorded the fuzzy controller takes about 40 seconds to generate the system response the PID controller takes 0.66 sec , fuzzy controller takes 40 sec and ANN based controller takes 0.25 sec. Hence we can conclude that system complexity of computation the response is very large for fuzzy controller and the ANN controller is fastest to compute the response hence the in terms of speed and computational complexity ANN based tank interacting system with disturbance is best.

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