

Comparative Study of Decoupler with Different Controllers for Two Inputs and Two Output System

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ABSTRACT: A process may have only one output and controlled by a single manipulated variable these type of process classified as single input single output system while in process control industries each process requires more than one control variables and any system having more than one control loops are known as multi input multi output or multivariable system. Here a two input two output (TITO) system is considered which is highly interacting multi-variable control system. In a interacting multi variable system existence of interactions or cross-coupling among the variables is responsible for poor performance. Decoupling control scheme is used for reducing the pairing between the controlled variables and manipulated variables. It minimizes or reduces the interaction by diagonalizing the system and two input two output processes are then decomposed by two individual decentralized SISO controllers. Two independent SISO system are further controlled by different controllers so that the system can trace the set point and yield good time response.

KEYWORDS: TITO system, decoupler, PID, IMC, Fuzzy logic controller, Matlab.

I. INTRODUCTION

Any industrial process is called multivariable system because many variables exist in the process and must be regulated. This system may be either non interacting or interacting. The use of the word 'multivariable' refers to those processes wherein many strongly interacting variables are involved. The multivariable system can have such a complex interaction pattern that the adjustment of a single set point causes a profound influence on many other control loops in the process. In some cases instabilities, cycling or even runaway result from the indiscriminate adjustment of a few set point[2]. In process industries the control of flow rate and the liquid levels in the tanks are two basic and major problems. Most of the time mixing treatment or the chemical operations is to be taken out in the tanks, but always the level of liquid in tanks must be controlled with the continuous regulation of flow rate between tanks. Thus we need to design the elements in such a way that the control over the variables will become easy.

The aim of the decoupling control system is to eliminate complicated loop interactions so that a change in one process variable will not cause corresponding changes in the other process variables. And decentralized controller is preferred in many MIMO dynamic processes because of its straight forward approach and simple to design, easy to tune, failure of one loop will not affect whole process. The modelling and controlling design is done using MATLAB tool box. So, with the help of conventional control, intelligent control the levels in the tanks are maintained as well as the interacting loops in the process is rendered non-interacting by the use of decoupler.

Relative Gain Array(RGA): Relative gain array is not only important tool for pairing manipulated variable and control variable but also used to predict the response of the system. This method is commonly used for the measure for process interactions.

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TITO WITH DECOUPLER AND CONTROLLERS

The schematic overview of the multivariable system represented by the two input two output tank water level is presented in figure 1. The control objective is to regulate the level h_1 & h_2 of the water in the two tanks by manipulating Q_{i1} & Q_{i2} water flows. The plant has two Q_{o1} & Q_{o2} are controlled outputs, G_{v1}, G_{v2} and G_{v12} are the controlling valves.

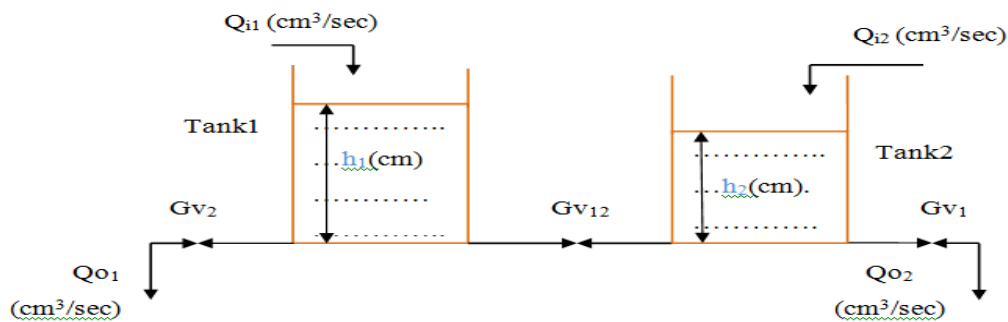


Fig1: A two- input-two-output interacting tank system

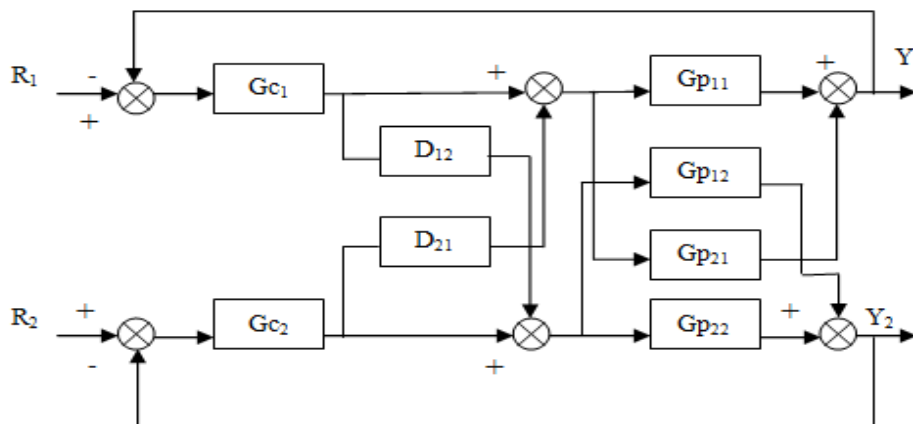


Fig 2. Decoupling control scheme with 1-2/2-1 pairing

In the control scheme of fig2, there are two feedback controllers G_{c1} and G_{c2} and two decoupling controllers D_{21} and D_{12} . The decouplers D_{ij} , $i, j=1...2$, have the role of cancelling the interaction effect from input j on the output i

II. LITERATURE REVIEW

A review of decoupling control methods was presented in [9] based on multiple models. The adaptive decoupling controllers are designed by attempting, training or optimization based on traditional decoupling methods such as diagonal matrix synthesis, characteristic locus analysis, inverse nyquist array, singular value decomposition, etc. However, the theory proposed here is not perfect and requires further investigation about its combination with multivariable decoupling technology and industrial process. This problem was later solved by in which a robust system identification method from step tests is presented first to SISO systems and then extended to TITO (Two-Input-Two-Output) processes. A lead-lag controller is designed from the FOPDT (First Order Plus Dead Time) model of the process. Simplified decoupler design is used and further modification is done in decoupler to prevent the decoupler elements from being unstable. The decentralized PID controllers are designed using frequency domain approach and auto-tuning steps are described. [2]

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III. MATHEMATICAL MODELLING

Let's consider a transfer function for a TITO system (Two interacting tank system) [1].

$$G(s) = \begin{pmatrix} \frac{22.89}{4.57s+1} e^{-0.2s} & \frac{-11.64}{1.81s+1} e^{-0.4s} \\ \frac{4.69}{2.17s+1} e^{-0.2s} & \frac{5.80}{1.81s+1} e^{-0.4s} \end{pmatrix}$$

Decoupler design equations

We want cross-controller d_{12} to cancel the effect of U_2 on Y_1 .

$$D_{12} G_{P11} U_{22} + G_{P12} U_{22} = 0 \tag{1}$$

Because $U_{22} \neq 0$ in general, then

$$\therefore D_{12} = -\frac{G_{P12}}{G_{P11}} = -\frac{A_{12} T_{11} s + 1}{A_{11} T_{12} s + 1} e^{-v_{11}(k_{22} - k_{21})s}$$

Similarly, we want d_{21} to cancel the effect of U_1 on Y_2 .

$$D_{21} G_{P22} U_{11} + G_{P21} U_{11} = 0 \tag{2}$$

$$\therefore D_{21} = -\frac{G_{P21}}{G_{P22}} = -\frac{A_{21} T_{22} s + 1}{A_{22} T_{21} s + 1} e^{-v_{11}(k_{22} - k_{21})s}$$

Let the resulting transfer function of the decoupled TITO system is denoted as $H(s)$,

Hence, $H(s) = G_c(s).D(s).G_p(s)$

A PID CONTROLLER

PID Control (proportional-integral-derivative) is by far the widest type of automatic control used in industry. Even though it has a relatively simple algorithm/structure, there are many subtle variations in how it is applied in industry. A PID controller will correct the error between the output and the desired input or set point by calculating and give an output of correction that will adjust the process accordingly.

$$e_a(t) = K_p \{e(t) + \frac{1}{T_i} \int_0^t e(t) dt + T_d \frac{de(t)}{dt}\}$$

B INTERNAL MODEL CONTROLLER

The IMC (Internal Model Control) principle requires a model of the process in order to compute a controller. The main idea is to design a controller/compensator which is based on the inverse of the model of the process. This approach works in the case of a traditional process. However, in our case, the non-minimum phase transmission zero will become an unstable pole for the controller and care must be taken in the controller design phase.

$$\check{G}_p(s) = \check{G}_{p+}(s).\check{G}_{p-}(s)$$

CFUZZY LOGIC CONTROLLER

The fig 3 shows the general structure of fuzzy interface system. Fuzzy logic control can play an important role because knowledge based design rules can easily be implemented in systems with unknown structure.

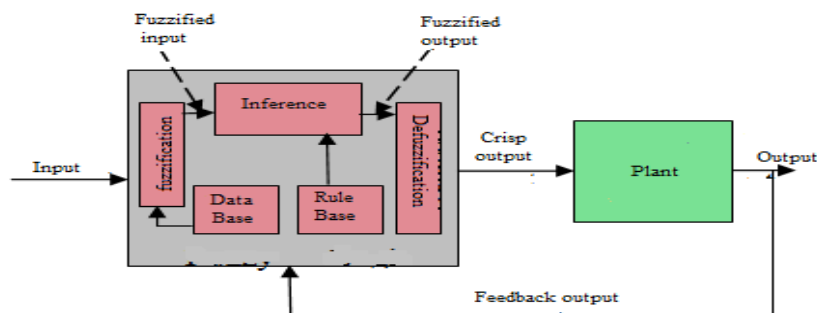


Fig 3: General structure of fuzzy interface system

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Designing fuzzy logic algorithm

Step 1: Fuzzification – It convert the system actual inputs values error (E) ie level of liquid and change in error (CE) i.e and output valve into linguistic fuzzy sets using fuzzy membership function. In fig4(a),4(b) & 4(c) shows membership function of error input & membership function of change in error input & membership function of output.

Step2: Rule base & inference engine – Fuzzy rule base is a collection of if-then rules that contain all the information for the controlled parameters.

Step 3: Defuzzification – This operation converts the inferred fuzzy control action into a numerical value at the output by forming the union of the outputs resulting from each rule.

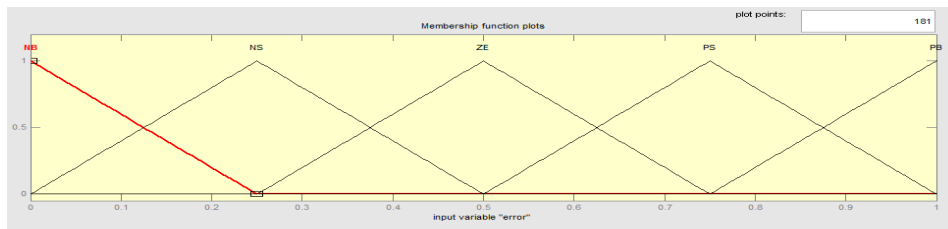


Fig: 4(a) Membership function of error

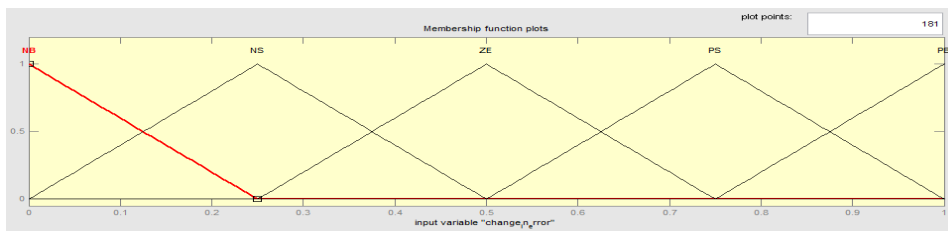


Fig: 4(b) Membership function of change of error

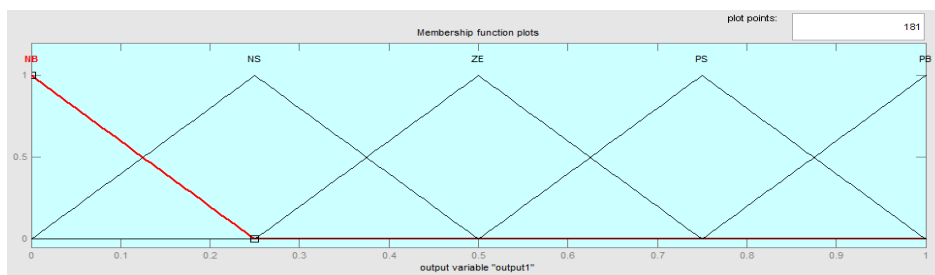


Fig: 4 (c) Membership function of output

Table: 1 Fuzzy rules

CE \ E	NB	NM	ZE	PM	PB
NB	ZE	ZE	NB	NB	NB
NM	ZE	ZE	NM	NM	NM
ZE	NM	NS	ZE	PS	PM
PM	NM	PM	ZE	ZE	PB
PB	PB	PB	ZE	ZE	ZE

Table: 1 contains 25 control fuzzy rule .

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There is five membership functions negative big (NG), negative medium (NM), zero (ZE), positive medium (PM), positive big (PB). These rules are employed for controlling the liquid level such as its reached to its specified value. As shown in the Table 1 the main idea of the rules is to bring set point to its specified level point.

Case 1 : If E is PM and CE is PB then output is PB. This implies that if flow rate is positive big then valve is close fast.
Case 2 : If E is PM and CE is PM Then output is ZE. This implies that if flow is OK, and flow rate is OK then the valve need not be varied.

IV. SIMULATION RESULT

1. SIMULINK OF TITO DECOUPLED SYSTEM WITH PID CONTROLLER

The fig 5 plant model for TITO system is modelled in MATLAB with the help of simulink library browser. Step response, sum, zero-pole form of transfer function, PID, transport delay, multiplexer and scope is taken from library and wired in required way for simulation.

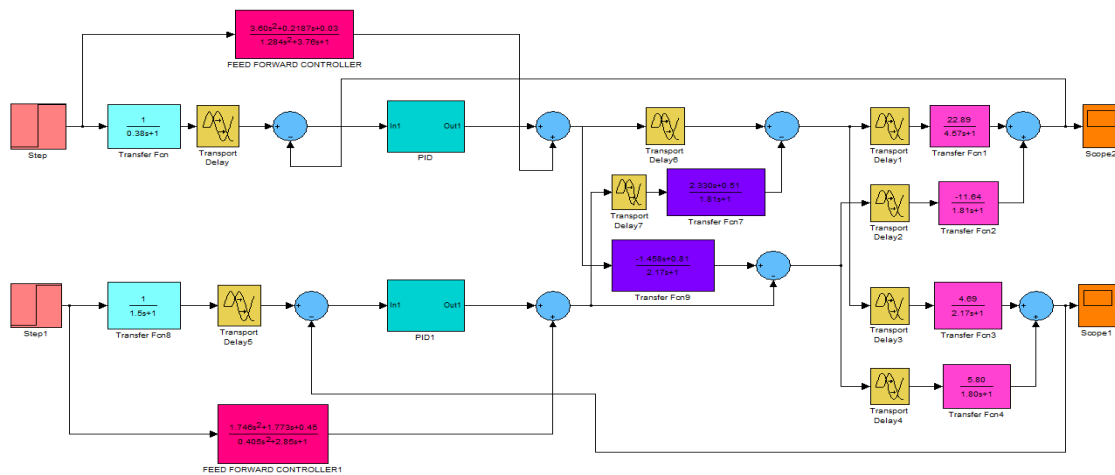


Fig: 5

1.1 Simulation of TITO decoupled system with PID controller

Fig 6 shows the response of TITO decoupled system with PID controller

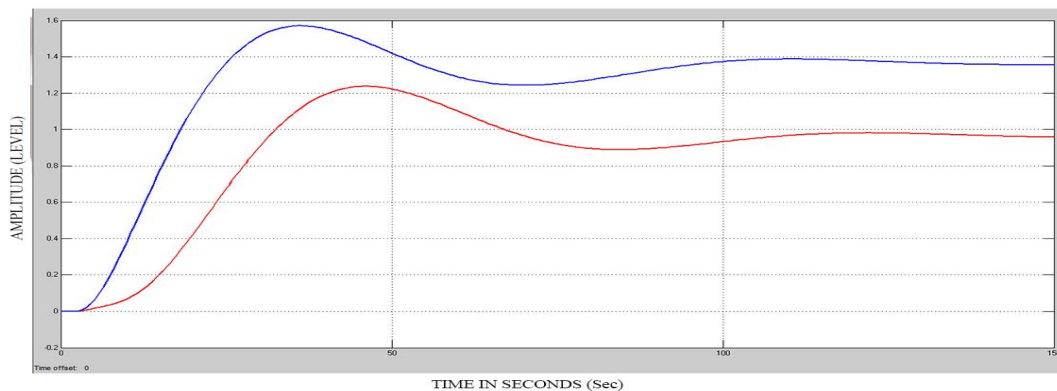


Fig: 6

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Discussion:

In fig 6 it has been observed that rise time is reduced but settling time and percent overshoot is still high due to the PID controller employed in the system. So, the system is not satisfactory.

2 Simulink of TITO decoupled system with IMC controller:

In fig 7 the additional blocks are employed in simulink plant model controlled by introducing IMC controller, block designed with is taken from simulink section transfer function with time delay

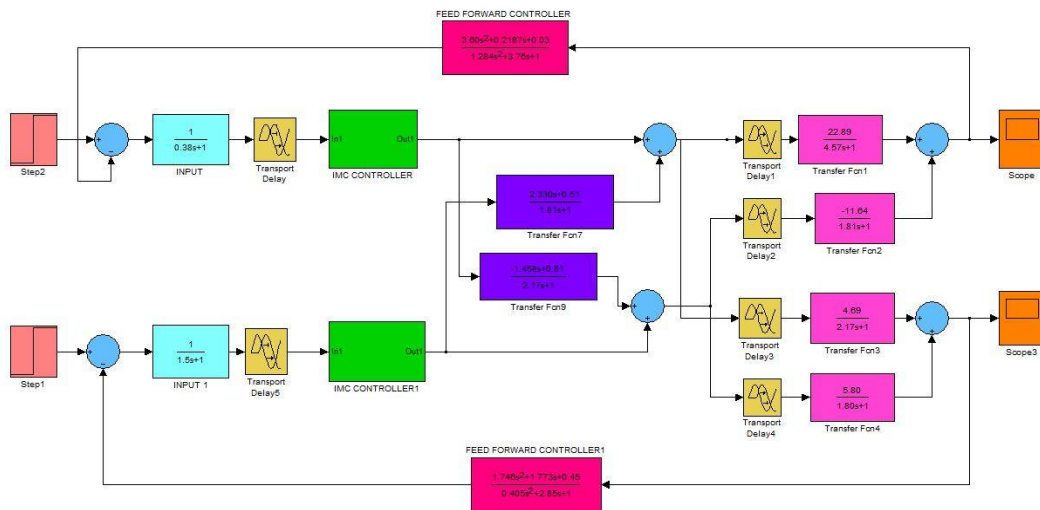


Fig: 7

2.1 Simulation of TITO decoupled system with IMC controller

Fig 8 shows the response of TITO decoupled system with IMC controller

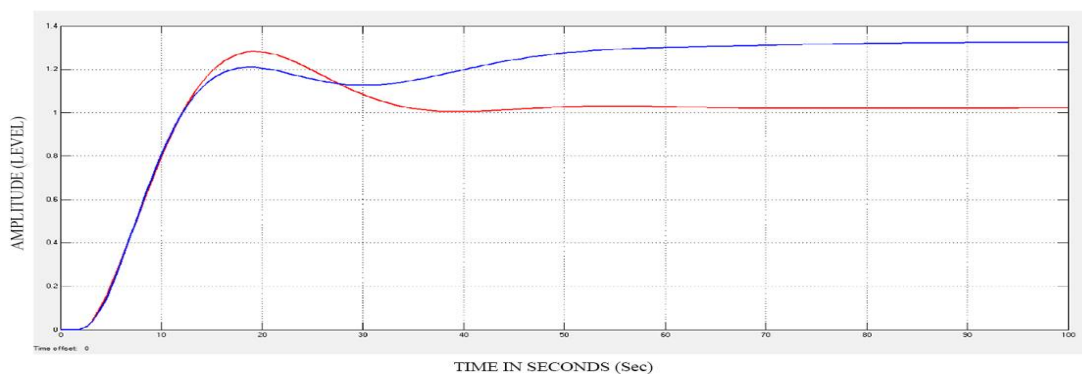


Fig 8

Discussion:

Fig: 8 shows the response of TITO decoupled system with IMC controller. It has been observed that rise time and percent overshoot is reduced and also has minimum settling time.

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RESULT: COMPARISON OF DIFFERENT CONVENTIONAL CONTROLLER

Table: 2

SYSTEM WITH CONTROLLERS	Rise time (in sec)	Settling time (in sec)	Overshoot (in %)	Peak time (in sec)
PID Controller	3.5442	9.5800	15.0000	3
IMC controller	0.3556	8.7667	9.5238	1

Discussion:

As the time responses of conventional controllers shown in Table 2. In a TITO decoupled system with conventional controller, IMC provides better result as compared to PID controller with respect to their time response performance.

INTELLIGENT CONTROLLERS USING IN SYSTEM

In this paper, fuzzy logic control approach has been taken. Fuzzy logic control is found most suitable for complex system, ill defined & nonlinear system.

3 Simulink of TITO decoupled system with fuzzy logic controller and PID controller:

In fig 9 the plant model for TITO system is modelled in MATLAB with the help of simulink library browser. The fuzzy logic system and PID controller is taken from library and wired in required way for simulation.

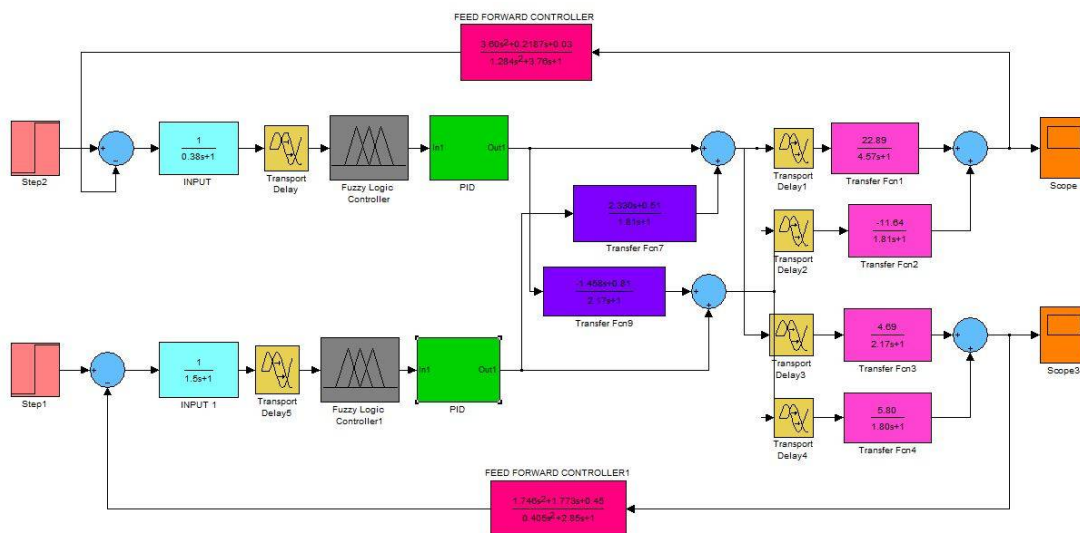


Fig: 9

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3.1 Simulation of TITO decoupled system with fuzzy logic controller and PID controller

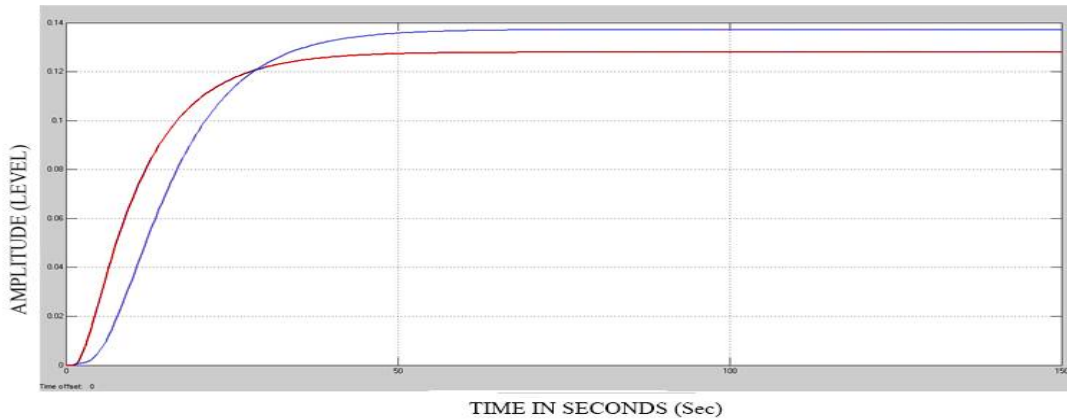


Fig:10

Discussion:

Fig: 10 shows the response of TITO decoupled system with PID controller. It has been observed that rise time and percent overshoot is quite high that leads to poor performance.

4 Simulink of TITO decoupled system with fuzzy logic controller and IMC controller:

In fig 11 the plant model for TITO system is modelled in MATLAB with the help of simulink library browser. IMC controller is a subsystem of transfer function and different transport delay and fuzzy system is taken from library.

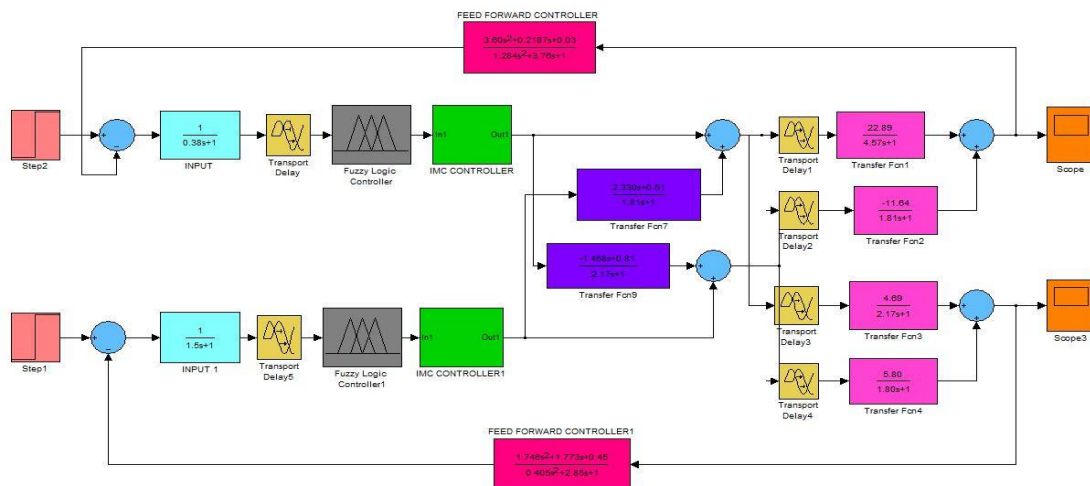


Fig :11

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4.1 Simulation of TITO decoupled system with fuzzy logic controller and IMC controller:

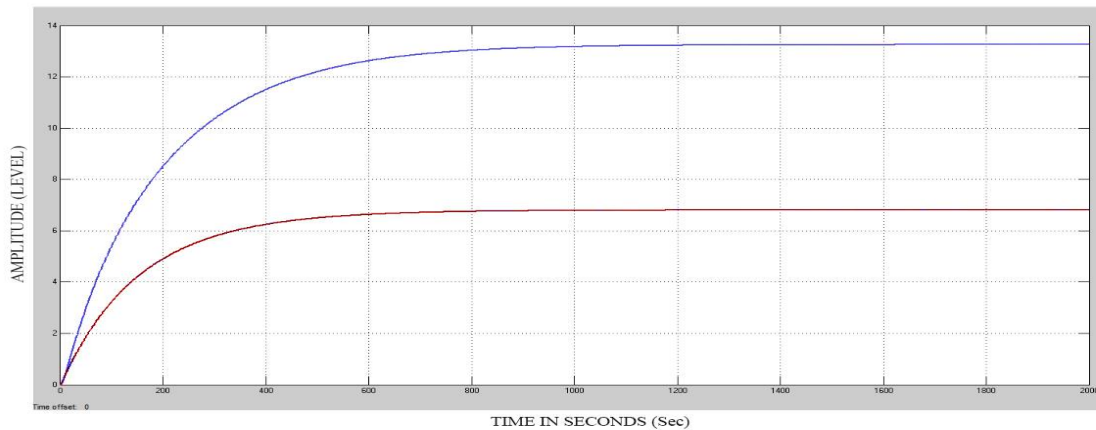


Fig 12

Discussion:

Fig: 12 shows the response of TITO decoupled system with IMC controller. It has been observed that rise time and percent overshoot is reduced

RESULT: COMPARISON WITHDIFFERENT INTELLIGENT CONTROLLERS

Table: 3

SYSTEM WITH CONTROLLERS	Rise Time (in sec)	Setting Time (In sec)	Overshoot (in %)	Peak time (in sec)
Fuzzy with PID	3.4313	12.5800	3.1010	13
Fuzzy with IMC	2.4313	7.9000	2.6786	12

V. CONCLUSION

Interacting system is a non-linear process. It cannot be controlled by single controller. Hence two controllers are implemented for each tank. For minimizing the interactions, decoupler and controllers are also designed. In this thesis, a comparative study of performance of different Conventional and Intelligent controller is studied. The aim of the proposed controller is to maintain the liquid at a specified level. Numerical simulation indicates that the fuzzy logic controller has more advantages than the conventional controller.

Performance analyses of conventional controller and intelligent controller have been done. It is observed that IMC based model gives a better response as compared to PIDconventional controller of the system and fuzzy IMC controller is the best controller as the compared to other intelligent controller.

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