ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

PERFORMANCE EVALUATION OF TWO TANK INTERACTING SYSTEM USING DIFFERENT TUNING METHODS

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ABSTRACT

Many process industries uses PID controller to control the parameters. To obtain the desired response the controller parameters are to be tuned effectively. Many researchers have presented their views to tune the controller parameters. In this paper, liquid level of a two tank interacting system is used as process. The dynamic response of the second tank is mainly depends on the first tank. The system is approximated to first order plus dead time model and applied various tuning methods like Zeigler-Nichols, Direct synthesis and Skogestad. The response of various methods observed and performance is evaluated and compared for real time two tank interacting system.

Keywords – *Interacting system, PID controller, Direct synthesis, Skogestad, Simulink, Performance indices*

I. INTRODUCTION

The most of industrial application of liquid level control is hazardous in chemical petroleum industries, paper chemical, mixing treatment industries, pharmaceutical & food processing industries. Level of tank and flow between tanks controlled using different controller like that PI , PID etc. the most widely used controller in industrial applications are the PI type controller because of good performance and easy to understand and installable structure. For highly nonlinear system, the performance of PI controllers can deteriorate quite fast. It is necessary to develop nonlinear PI controllers for controlling nonlinear processes. PI controller has high overshoot and large settling time so to overcome this disadvantage of PI controller we use PID controller. The proportional-integral-derivative (PID) controllers are used for a wide range of process control, motor drives, magnetic and optic memories, automotive, flight control, instrumentation, etc. In industrial applications, PID type controllers were widely used. With its three-term functionality covering treatment to both transient and steady-state responses, proportional- integral-derivative (PID) control offers the simplest and yet most efficient solution to many real-world control problems.

More than 90% of the process industries are using PI or PID controller. In 1942 Zeigler-Nichols proposed the set of tuning rules to PID controller. The Ziegler-Nichols method is widely used for Controller Tuning. One of the disadvantages of this method is prior knowledge regarding plant model. Once tuned the controller by Ziegler-Nichols method, a good but not optimum system response will be reached. Skogested tuning is a model based tuning technique. An important advantage of the SIMC rule is that there is a single tuning parameter (τ_c) that gives a good balance between the PID parameters. The only exception is it does not give good results for pure time delay processes. In the Direct Synthesis (DS) method, the controller design is based on a process model and a desired transfer function. It uses an identified process model in conjunction with a user specified closed loop response characteristic. An advantage of this approach is that it provides insight into the role of the model in control system design.

II. PROCESS DESCRIPTION

The experimental setup of the process is shown in Fig.1. It consists of pumps, control valves, process tanks, overhead tank, differential pressure transmitter, level transmitter, rotameter. Instrumentation panel consists PI, PD and PID controller, main power supply switch, pump switches, auxiliary switches for individual components. Fluid level in the tank is measured by level transmitter (LT). Output of LT is given to the data

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acquisition setup. It consists of analog to digital converter and digital to analog converter. The differential pressure level transmitter measures the flow by sensing the difference in level between the tanks. The DPLT then transmits a current signal (4-20mA) to I/V converter. The output of I/V converter is given to the interfacing hardware associated with the personal computer (PC). A control algorithm is implemented in software. It compares and takes corrective action on the control valve based on how much control valve open or close. The controller compares the controlled variable against set point and generates manipulated variable as current signal (4-20mA). Here the controlled variable is the level (h2) and the manipulated variable is the flow rate (qin). The control valve gives restriction to the flow through the pipeline and hence the desired level is achieved. The technical specifications are given in table1.

Fig 1: Experimental setup of two tank interacting system

Table 1: Specifications of experimental setup

Components	Range
Control valve	Height–52cm, diameter-9.2cm
Level transmitter	Capacitive Type Range–550mm, Output – 0-5VDC
Rotameter	Range–(0-1200)LPH
Control valve	Pneumatically actuated single sealed globe control valve Air to open
Pump	Single Phase AC motor Centrifugal regenerative 0.5HP
Electro pneumatic actuator	Input – (4-20) mA Output – (3-15)psi Supply – 20psi

*A. **Mathematical Modeling of Two Tank Interacting Level Process***

The process consisting of two interacting liquid tanks shows in figure 2. The height of the liquid level is h1 (cm) in tank1 and h2 (cm) is tank2. Volumetric flow into tank 1 is qin (cm3/min), the volumetric flow rate from q1 (cm3/min), and the volumetric flow rate from tank 2 is q0 (cm3/min). Cross sectional area of tank1 is A1 (cm2) and area of tank2 is A2 (cm2). [10] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences. Elements and speed vectors were thought to be inaccessible, along these lines a NN eyewitness was intended to recoup the limitless states. At that point, a novel NN virtual control structure which permitted the craved translational speeds to be controlled utilizing the pitch and the move of the UAV. At long last, a NN was used in the figuring of the real control inputs for the UAV dynamic framework. Utilizing Lyapunov systems, it was demonstrated that the estimation blunders of each NN, the spectator, Virtual controller, and the position, introduction, and speed following mistakes were all SGUUB while unwinding the partition Principle.

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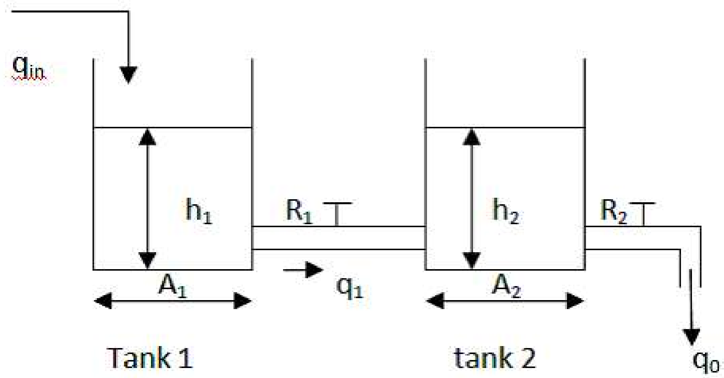

Fig 2: Two tank interacting system

For Tank-1,

$$A_1 \frac{dh_1}{dt} = q_{in} - q_1 \tag{1}$$

Assume linear resistance to flow,

$$q_1 = \frac{h_1 - h_2}{R_1}$$

$$A_1 \frac{dh_1}{dt} = q_{in} - \frac{h_1 - h_2}{R_1} \tag{2}$$

$$A_1 R_1 \frac{dh_1}{dt} = R_1 q_{in} - (h_1 - h_2) \tag{3}$$

Let A_1R_1 be the time constant of the Tank-1

$$T_1 \frac{dh_1}{dt} + h_1 - h_2 = R_1 q_{in} \tag{4}$$

by applying Laplace transforms on both sides

$$h_1(S) = \frac{R_1 q_{in}(S)}{T_1 S + 1} + \frac{h_2(S)}{T_1 S + 1} \tag{5}$$

For Tank-2,

$$A_2 \frac{dh_2}{dt} = q_1 - q_0 \tag{6}$$

Assume linear resistance to flow

$$q_0 = \frac{h_2}{R_2}$$

Substitute q_1 and q_0 in equation(6)

$$A_2 \frac{dh_2}{dt} = \frac{h_1 - h_2}{R_1} - \frac{h_2}{R_2} \tag{7}$$

$$A_2 R_2 R_1 \frac{dh_2}{dt} = (h_1 - h_2) R_2 - h_2 R_1$$

Let A_2R_2 be the time constant of the Tank-2

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$$T_2R_1\frac{dh_2}{dt}+h_2(R_1+R_2)=h_1R_2$$

by applying Laplace transforms on both sides

$$T_2R_1Sh_2(S)+(R_1+R_2)h_2(S)=R_2h_1(S) \quad (8)$$

by solving the equation (8) and equation (5)

$$\frac{h_2(S)}{q_{in}(S)}=\frac{R_2}{T_1T_2S^2+S(T_1+T_2+A_1R_2)+1} \quad (9)$$

Equation (9) is a transfer function of interacting system.

B. Determination of plant transfer function

The transfer function of two tank interacting system was evaluated by using LabVIEW programming. Open loop system using LabVIEW was shown figure 3. Initially a flow rate of 100LPH is applied to the system. The output of the system reaches steady state value of 12.5mm in tank1 and 11mm in tank2. This is called initial state of system. A sudden change in the flow rate of 200LPH is applied to the system. The output of the system reaches steady state value of 31.5mm in tank1 and 27.9mm in tank2. This is called final state of system. Experimental results are tabulated in the table2.

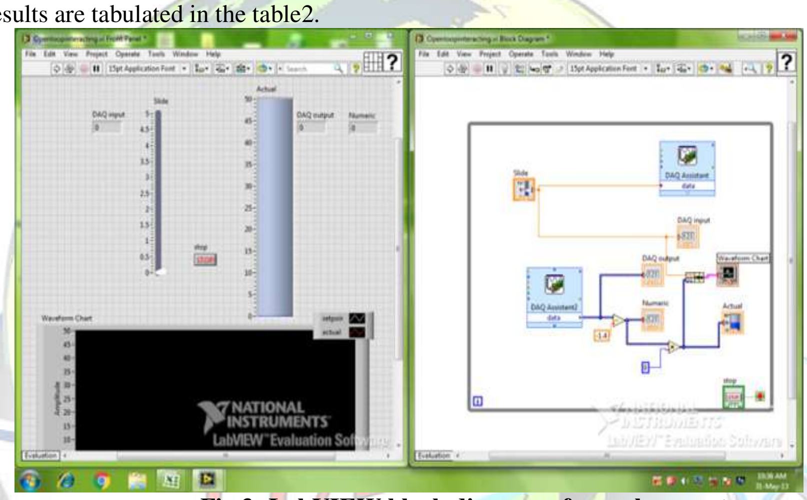

Fig 3: LabVIEW block diagram of open loop system

Table 2: Experimental results for a real time system

Flow rate (LPH)	Height in tank1 (mm)	Height in tank2 (mm)
100	12.5	11
200	31.5	27.9

We know that,

$$R_1=\frac{dh_1}{dq} \quad \text{and} \quad R_2=\frac{dh_2}{dq}$$

Substituting measured value in above equation

$R_1 = 1.9sec/m^2$

$R_2 = 1.69sec/m^2$

Area of tank1 and tank 2 = $0.66\ m^2$

Time constant $T_1 = 1.25$sec and $T_2 = 1.11$sec.

The transfer function of interacting tank system

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$$\frac{h_2(S)}{q_{in}(S)} = \frac{1.69}{1.38S^2 + 3.47S + 1}$$

Transfer function of system in s-domain, that present gain of system is 1.69 with two poles at -0.33 and -2.18.

III. DESIGN OF FOPTD MODEL

Sundaresan and Krishnaswamy proposed a simple method for fitting the dynamic response of systems in terms of first order plus time delay (FOPTD) transfer function.

$$G(S) = \frac{K}{\tau S + 1} e^{-\theta S}$$

The open loop process gain (K) is the ration of change in output by change in input. The time delay (θ) and process time constant (τ) are calculated based on the times t1 and t2 at which the 35.3% and 85.3% of the step response of the open loop system. The response is shown in figure 4.

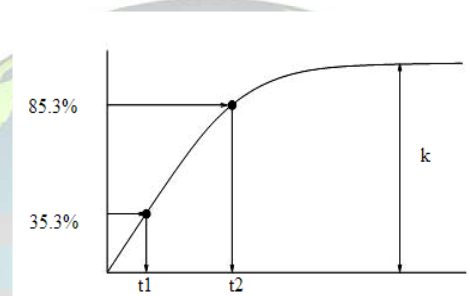

Fig 4: Open loop response of the process for step input

The time delay (θ) and process time constant (τ) can be obtained from the following equations:
$\theta = 1.3t_1 - 0.29t_2$
$\tau = 0.67(t_2 - t_1)$

From the sigmodial response, times t_1 and t_2 are calculated for the system.
t_1 =1.78sec and t_2 =6.20sec
Open loop gain, K=1.683
Time delay, θ = 2.25sec
Time constant, τ = 2.96sec
The transfer function of FOPTD model is

$$G(S) = \frac{1.683}{2.96S + 1} e^{-2.25S}$$

IV. TUNING METHODS

A. Ziegler-Nichols Method

The Ziegler-Nichols design methods are the most popular methods used in process control to determine the parameters of a PID controller [2]. Ziegler-Nichols tuning methods (ZN tuning methods) are the principal methods used in PID controller tuning. The two methods are called step response method and ultimate frequency method [6]. The unit step response method is based on the open-loop step response of the system. The unit step response of the process is characterized by two parameters, delay L and time constant T and these are used in calculating the controller parameters. The parameters for PID controllers obtained from the Ziegler-Nichols method are

$$K_p = \frac{1.2K}{L}, \tau_i = 2L, \tau_d = 0.5L$$

B. Skogested Method:

Skogestad's method is a model-based method. It is assumed that you have mathematical model of the process (a transfer function model). It does not matter how you have derived the transfer function it can be a

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model derived from physical principles, or from calculation of model parameters (e.g. gain, time-constant and time-delay) from an experimental response, typically a step response experiment with the process (step on the process input). Skogestad‟s tuning method is a model-based tuning method where the controller parameters are expressed as functions of the process model parameters.

$$K_p = \frac{\tau}{K(\tau_c + \tau)}; \tau_i = \min[\tau, K(\tau_c + \tau)]\ ;\ \tau_d = 0\ \text{, where } \tau_c = \theta$$

C. Direct Synthesis Method

The design methods for PID controllers are typically based on a time-domain or frequency-domain performance criterion. In the direct synthesis (DS) approach, however, the controller design is based on a desired closed-loop transfer function. DS design methods are usually based on specification of the desired closed-loop transfer function for set-point changes. DS method for set point tracking, a simple controller design method with only one controller in a single feedback loop for all classes of integrating processes has been considered. The desired output behavior of the closed loop can be specified as a trajectory model based on the process to design the required form of the controller. With the conventional controllers, there may be problems like overshoot and settling time. The initial value of the tuning parameter can be taken as equal to half of the time delay of the process to get good control performance. If not, then, the tuning parameter can be increased from this value till good nominal and robust control performance are achieved.

$$K_p = \frac{\tau + \theta}{K\tau_c}\ ;\ \tau_i = \tau + \theta\ ;\ \tau_d = \frac{\tau\theta}{\tau + \theta}$$

V. RESULTS AND OBSERVATIONS

Simulink diagram of transfer function of the system and FOPTD model of the experimental setup was shown in figure 5. The step response of the FOPTD model is as similar to the step response of the transfer function and is shown in figure 6.

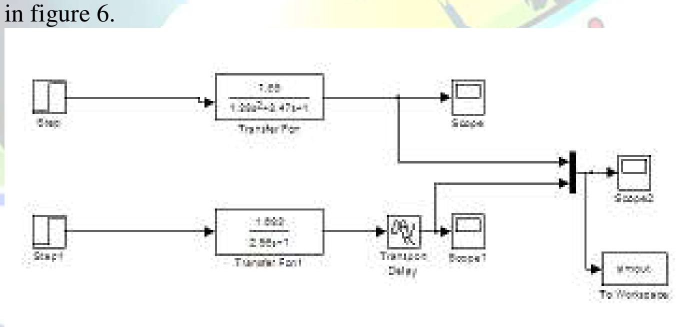

Fig 5: Open loop simulink diagram of transfer function and FOPTD model.

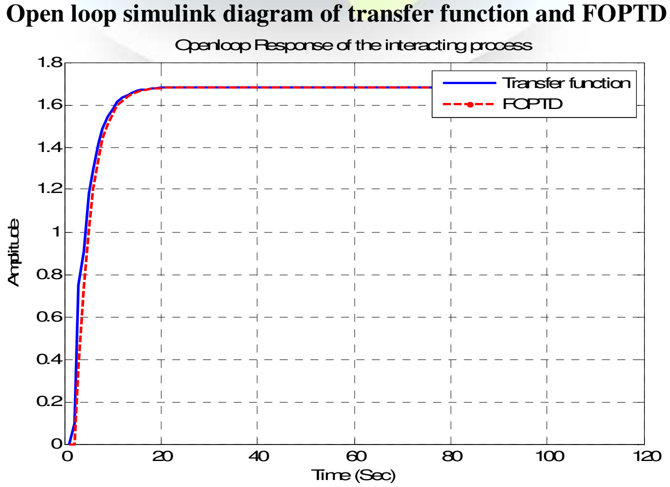

Fig 6: Open loop response of transfer function and FOPTD model.

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LabVIEW block diagram of closed loop system is shown in figure 7. In closed loop LabVIEW block diagram, PID controller is used to manipulate the controlled variable. In figure 8, the closed loop simulink diagram of the process was shown.

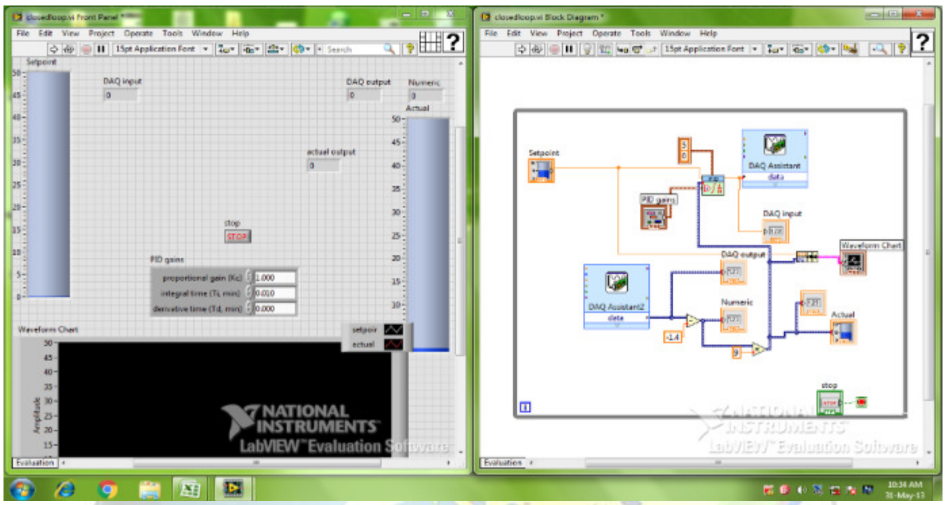

Fig 7: LabVIEW block diagram of closed loop system

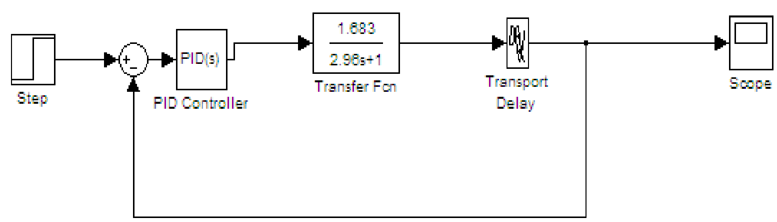

Fig 8: Simulink model for closed loop response

The controller parameters are calculated using Ziegler Nichols, Skogested and Direct synthesis tuning methods and tabulated in table 3. The desired height of the tank2 is set to 25mm. The simulated response of the process using different tuning methods had shown in figure 9, 11 and 13. The real time response of the process using different tuning methods had shown in figure 10, 12 and 14.

Table 3: Controller parameters using different tuning methods

Tuning method / Controller parameters	Ziegler Nichols Method	Skogested Method	Direct Synthesis Method (τ_c=8)
K_p	0.937	0.39	0.4128
K_i	0.208	0.131	0.0792
K_d	1.054	0	0.5242

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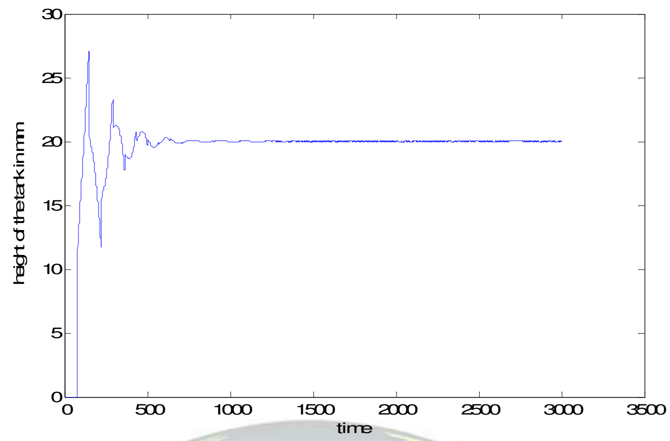

Fig 9: Simulink response for Ziegler Nichols method

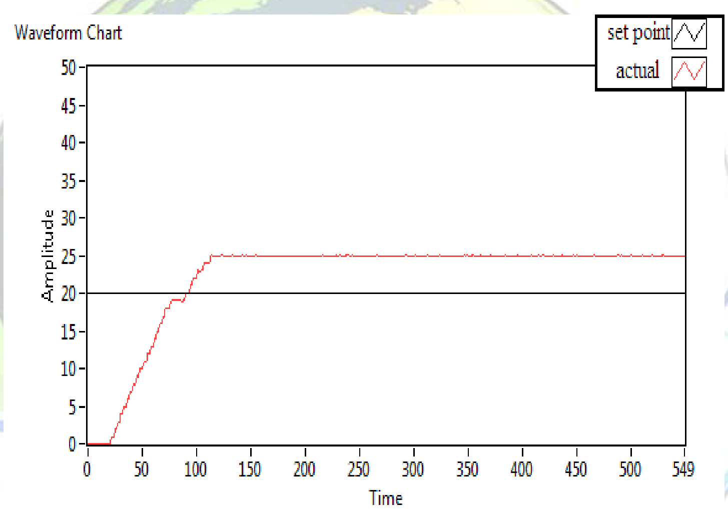

Fig 10: Real time response for Ziegler Nichols method

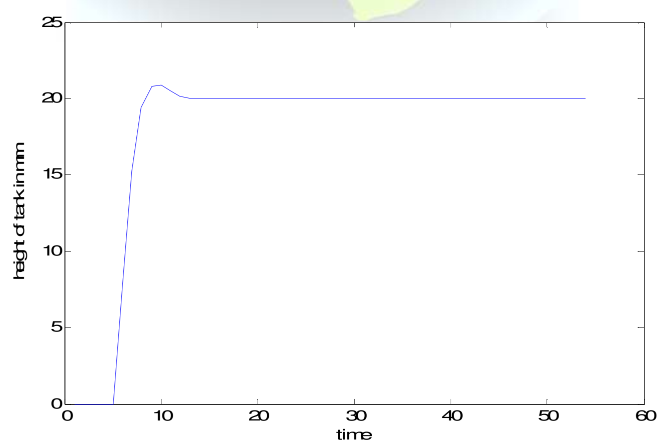

Fig 11: Simulink response for Skogested method

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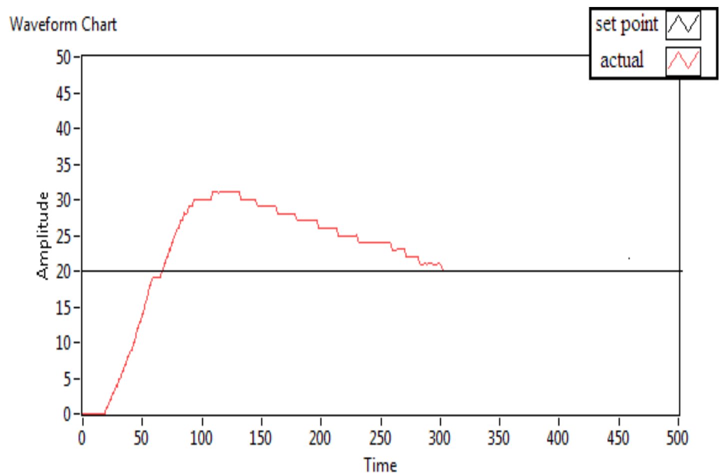

Fig 12: Real time response for Skogested method

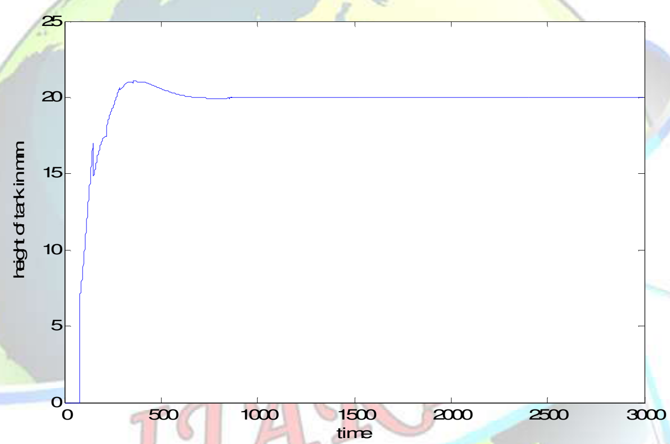

Fig 13: Simulink response for direct synthesis method

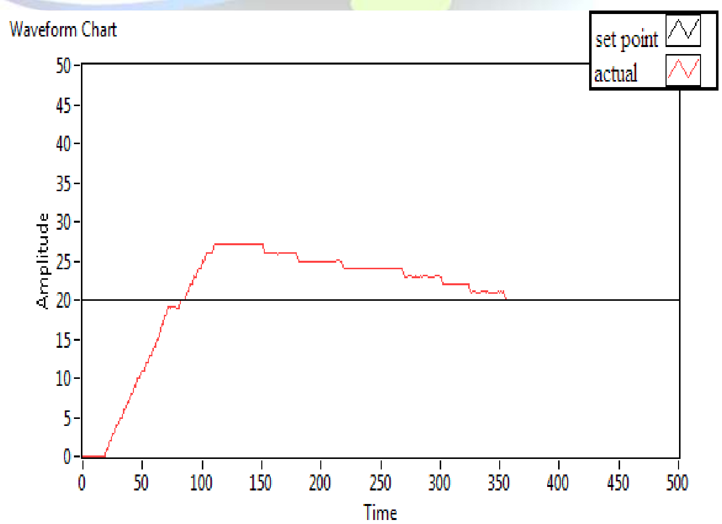

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Fig 14: Real time response for direct synthesis method

Table 4: Time domain performance of real time process using different tuning methods

Parameter	Ziegler Nichols Method	Skogested Method	Direct Synthesis Method (τ_c=8)
Rise time (sec)	31.359	32.3109	46.9289
Settling time (sec)	126.925	324.5932	306.5880
Peak overshoot	23.2814	31.0709	24.0113
Peak time 90sec)	122	117	194
ISE	2.519	3.825	3.333
IAE	3.708	4.994	4.577
ITAE	18.07	20.65	19.63

In Ziegler Nichols method, the peak over shoot is very high in simulation but in real time it is less compared to other methods. When this method is applied to real time system, the steady state value obtained is greater than the given set point. The values of ISE, IAE, ITAE of Ziegler Nichols method are less when compared to other methods.

The peak over shoot of Skogested method is less than other methods in simulation, but in real time it is high compared to other methods. The ISE,IAE,ITAE values of Skogested method are higher than the other methods.

The settling time for Direct Synthesis method in simulation is larger than the settling time obtained in real time. The peak over shoot for Direct Synthesis method is less when compared to peak over shoot of Skogested method. The ISE, IAE, ITAE values of Direct Synthesis method are moderate.

VI. CONCLUSION

In this paper, developed the transfer function of two tank interacting system and FOPTD model of the system. Understanding the dynamic behavior of a process is essential to the proper design and tuning of a PID controller. Ziegler Nichols, direct synthesis and Skogested methods are used to tune the controller. All the methods are compared to get the optimum condition for the process model. LabVIEW is used to acquire the real time experimental values. The performance analysis for all the methods has been analyzed using MATLAB simulink. The results indicated that response using Direct Synthesis tuning method is slightly better than those of the Ziegler Nichols and Skogested methods for real time two tank interacting system.

REFERENCES

[1] L.ThillaiRani, N.Deepa, S.Arulselvi, "Modeling and Intelligent Control of two tank Interacting Level Process", International Journal of Recent Technology and Engineering (IJRTE),Volume-3, Issue-1, 2014.
[2] Anandanatarajan R, Chidambaram M, Jayasingh.T. "Limitations of a PI controller for a first order non-linear process with dead time",ISA Transactions,45, pp.185-200, 2006.
[3] Bhuvaneswari N S, Uma G, Rangaswamy T R, "Neuro based Model Reference Adaptive control of a conical tank level process", Control and Intelligent Systems, 36(1), pp.1-9, 2008.
[4] Bhuvaneswari N S, Uma G, Rangaswamy T R, " Adaptive and Optimal Control of a Non-Linear process using Intelligent Controllers", Adaptive soft computing, 9(1), pp.182-190, 2008.
[5] Ravi V R, Thagarajan T, " A de-centralized PID Controller for Interacting Non Linear systems", Proceeding of IEEE 2011 International Conference on Emerging trends in Electrical and Computer Technology, pp.297-302, 2011.
[6] Bhuvaneswari N S, Praveena R,Divya R , "System Identification And Modelling For Interacting And Non- Interacting System Using Intelligence Techniques ", IJIST-2012 ,Volume-2,no-5,pp.23-25, 2012.
[7] Astrom, K.J and agglund, T. H, "Revisiting The Ziegler–Nichols Step Response Method For PID Control‟, J. Process Control, 14, pp. 635–650, 2004.
[8] Chen, D.E. and Seaborg, B.,"PI/PID Controller Design Based On Direct Synthesis And Disturbance Rejection‟, Ind. Eng., 2002.
[9] Michael, W. , Foley, M.W , Julien, R.H and Copeland, B.R. (2005),„A Comparison Of PID Controller Tuning Methods‟, Can. J. Chem. Eng. 83 pp. 712–722.
[10] Christo Ananth,"A Novel NN Output Feedback Control Law For Quad Rotor UAV",International Journal of Advanced Research in Innovative Discoveries in Engineering and Applications[IJARIDEA],Volume 2,Issue 1,February 2017,pp:18-26.
[11] Ziegler, J.G. and Nichols, N.B. "Optimum Settings For Automatic Controllers", Trans. ASME, pp.759–768, 1942.
[12] Manigandan, T.; Devarajan, N– Sivanandam. S. N., "Design of PID Controller using reduced order model", Acad. Open Internet J., 15, 2005.
[13] Sundaresan, K. R., Krishnaswamy, R. R., Estimation of Time Delay, Time constant Parameters in Time, Frequency and Laplace Domains, Journal of Chemical Engineering., 56, p.257, 1978.

[14] R D Kokate and L M Waghmare, "Review of Tuning Methods of DMC and Performance Evaluation with PID Algorithms on a FOPDT Model", International Journal of Control and Automation, Vol. 4 No. 2, 2011.

[15] Saeed Tavakoli and Mahdi Tavakoli, "Optimal tuning of PID controllers for first order plus time delay models using dimensional analysis", The Fourth International Conference on Control and Automation (ICCA'03), 10-12, 2003.

[16] G.K.I.Mann, B.G.Hu and R.G. Gosine, "Time –domain based design and analysis of new PID tuning rules", Process Control Appl.,Vol.148, No.3, 2001.

[17] N. Gireesh and G. Sreenivasulu, "Comparison of PI Controller Performances for a conical tank process using different tuning methods", IEEE International Conference on Advances in Electrical Engineering, 2014.