

DESIGN OF CONTROLLER FOR NON-LINEAR HOPPER TANK SYSTEM

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering Degree in Electronics and Instrumentation Engineering

By

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of ANANDHA NARAYANAN (37180002) who have done the Project work as a team and carried out the project entitled **“DESIGN OF CONTROLLER FOR NON-LINEAR HOPPER TANK SYSTEM”** under my supervision from September 2020 to March 2021.

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DECLARATION

I am ANANDHA NARAYANAN P hereby declare that the Project Report entitled “**DESIGN OF CONTROLLER FOR NON-LINEAR HOPPER TANK SYSTEM**” done by us under the guidance of **Dr.D. MARSHIANA, M.E., Ph.D** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Instrumentation Engineering.

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ABSTRACT

This project work focuses on the design of conventional controllers, which can be used for the control of non-linear systems to provide a desired level of a process tank. The nonlinear systems take's up for the study is Hopper tanks because of its use in the field of Pharmaceutical, Petro chemical, water treatment and paper making industries. Its non-linearity is due to the cross-sectional behavior of the process. It consists of two parts Conical Tank for easy flow of solid, viscous liquids and a cylindrical tank for storage of materials. It is used for the evacuation of products without wastage is possible. The closed loop performance is determined to obtain the desired level control using conventional PI, controllers for various tuning methods. The major advantage of this method is simplicity. Simulation results using MATLAB software to determine the outperformance of controller techniques.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In various industries the control of process parameters plays its major role. The issues include the control the main parameters like level, pressure, temperature and flow. It is essential to control the first process parameters, when failing occurs in the process do various escort to make severe shutdown in process industry. So many process industries like (petrochemical industries, Paper making required to continue the level of reservoir at meticulous set point. The majority of the industries deal with nonlinear process tanks such as spherical, conical, Hopper tanks. The direct Control of non-linear nature of process cistern Present a exigent task. It is generally due to its cross sectional non-linearity behavior and persistently varying shape. Therefore, the Hopper nature process is in used up for current study. In various process stations like petrochemical industries, Paper making Industries, water treatment Industries, etc., the foremost problem is to organize the process parameters and to manage the preferred setpoint. Most of the industries deal with non-linear process tank such as conical, spherical, hopper tanks.

The major aim of this projectwork is to control the level in a nonlinear system. The nonlinear system considered for the study purpose is a hopper tank process. Owing to its shape the raw resources can be easily removed or disposed in a hopper tank and the work process can be done very quickly. It is capable of handle the storage quantity while large storing of process materials. It is because of the cylindrical shape which is present at the top of the hopper tank .Due the at the top portion increased quantity of materials can be loaded in larger amount, based on the necessities. It provides a rapid and disinfected clean-up. The raw substance may consist of solvents, viscous liquids, slurries, and solids. To surpass up the rusting and preserve the flow or movement of the process material regularly can be done by using the lower part of the conical element presented at the bottom of the structure.

The majority of the contamination occurrence owing to spillage, overloading of tank, concentrated practice and poor behavior facilities can be avoided. The principle mission of the controller design is to bring about the ideal operational conditions and to design the controller to attain its the largest part off avorable execution performance.

1.2 Aim of the project:

The aim of the project is to control the level of the tank in a nonlinear system. The nonlinear structure considered for the study is a hopper tank system. It is said to be nonlinear because of its shape because of the area of cross section. To control the level of the tank mathematically model is designed by considering the Level as the control variable and flow as the manipulated variable. Using the transfer function derived from mathematical model the specifications of tank is determined and it gives the Transfer function of Hopper tank with the first order system. The Ziegler Nichols controller Tuning, Cohen coon tuning, internal model control, Shinsky tuning constant method is designed to determine the servo and regulatory response of the system.

1.3 Scope of the project:

In this project the chapters are organised as follows. In chapter the introduction about the project is described. In chapter 1 the aim and scope of the project and in chapter 2 literature survey and in chapter 3, the statistical modeling of the Hopper tank arrangement to find out the transfer function is described. In chapter 3 the Ziegler Nichols controller Tuning, Cohen coon tuning, and , internal model control, Shinsky tuning constant method was discussed to determine the P, PI and PID controller values. To conclude, the outcome and conclusion are discussed in chapter 4 and chapter 5

CHAPTER2

LITERATURE SURVEY

2.1 Literature Survey

1. Vinothkumar. C, Esakkiappan. C, “Level Control of Nonlinear Hopper Tank Process in Pharmaceutical Industry using Ziegler Nicholas and Cohen Coon Tuning Techniques”, International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-8 Issue-10, August 2019.

The research paper, deals with the design and its corresponding simulation outcome of various conventional controllers on non linear hopper tank system. They are obtainable to manage a most wanted level in the process tank. The hopper tank is a non linear process that can be used for this study. It is used in various operating in the field of Pharmacy, Petroleum plants and chemical industries. mass departure of process materials without wastage is preferable due to its non-linearity shape of hopper tank's cross sectional behavior. The open loop performance are evaluated to attain the desired level by considering the conventional controllers like PI, PID rollers for different tuning techniques similar to step response with respect to Ziegler Nicholas and open loop process reaction curve method. The main gain of this technique is simplicity. The correlation between these tuning process are implemented by Simulink model using MATLAB software & Compared the arrangement of controllers with hopper process tank

2. Suresh Manic Kesavan, Tvn Padmesh, Chan Woei Shyan , “CONTROLLER TUNING FOR NONLINEAR HOPPER PROCESS TANK – A REAL TIME ANALYSIS” Journal of Engineering Science and Technology EURECA 2013 Special Issue August (2014) , pp.59 – 67

In this research, Proportional + Integral + Derivative (PID) technique was designed and its real time execution was projected for a nonlinear hopper tank system in categorize to resolve servo and regulatory problem. first of all, recognition of process transfer function is done during the implementation of the process in real time experiment and it is practically developed using the conventional PID controller. Then tuning techniques has been planned which include the multiple methods like Cohen-coon (CC), Ziegler & Nichols (ZN), Internal Model Control (IMC) and Tyreus & Luyben (TL). The optimization of various tuning methods and its parameters are considered up with Integral Square Error (ISE), Integral Absolute Error (IAE) and Integral Time Absolute Error (ITAE). The investigational results illustrate that TL and ZN tuning technique are appropriate in controlling nonlinear hopper level tank system

3. J.Indirapriyadharshini, T.Sivaranjani, R.Gokila, "Performance Analysis of Internal Model Control and Modified Internal Model Control for Two Tank Interacting and Non-Interacting Liquid System", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8, Issue-8, June 2019

In the developed process industries, currently numerous demanding control issues are present because of rapid dynamic changes in process parameters. These changes might be occur since the process characteristics are connected with linear behavior, limitation of process variable and manipulated variable values during operation. Liquid level control in tanks and linking the tanks are elementary industrial difficulty and also most essential needs. In many cases, the tanks are connected in parallel and series manner and reveal non-linear distinctiveness. This paper deals with the level control of two tank system which is connected in interacting and non-interacting mode. This paper demonstrates the optimized performance of Internal Model Control (IMC) and modified Internal Model Control (MIMC) for the system connected in interacting and non-interacting tanks in terms of transient response characteristics.

4) KiranH.Raut ,Dr.S.R.Vaishnav “Performance Analysis of PID Tuning Techniquesbased on Time Response specification” INTERNATIONAL JOURNAL OF INNOVATIVERESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROLENGINEERING Vol. 2, Issue 1, January 2014

Corresponding Integral-Derivative (PID) regulators are broadly utilized in industrialized control framework because of the concentrated measure of boundaries to be tuned. Differing the information boundaries of a PID regulator is incredibly critical in PID control. The reason for relative (KP), subsidiary (Kd) and indispensable (KI) constants are distinguished as tuning of PID regulator. This composition presents PID tuning rules for higher request framework. The show of PID tuning strategies are investigated and looked at on wellspring of time reaction details

CHAPTER 3

METHODOLOGY

3.1 Mathematical Model

A mathematical model regularly develop a function having a system with a set of different variables and equations which states that the system is highly established by the relationship that states the set of various function. It also develops the input and output relationship of any functions. If one or more number of the equations are based on the purpose functions or constraints with a Nonlinear equation, then the representation is identified as a nonlinear representation.

3.1.1 Need for Modelling:

- A mathematical model is developed using the process control technique.
- It should be as simple as the explanation that the process reacts with a variety of inputs
- The development process are very costly
- To be appropriate with the basic controller techniques.

3.1.2 Mathematical model for hopper method:

The Mathematical model of a Hopper tank was carried out. Since its area of cross section varies with respect to its height, it is assumed to be a nonlinear in nature. To maintain the flow inside the process equipment, the Level is considered as the control variable and then it measures the manipulated variable of the designed process. The design of non-linear hopper process tank is the combination of cylindrical and conical Region. The mathematical model of the conical tank can be determined, by considering the following assumption.

The Calculated perfect of a Hopper tank is considered. Because of its area of cross section, it is said to be a nonlinear system. To control the input flow of the tank the Level is taken as the mechanism adjustable and then flow of the tank as the manipulated variable. The modeling of non-linear hopper process tank is the combination of cylindrical and conical area. The mathematical model of the conical tank can be determined, by since the following assumption.

- Mechanism variable (level)
- The operated variable (tank flow)
- Monitoring inflow of the boiler.

The figure1 shows the representation figure of the Hopper tank system

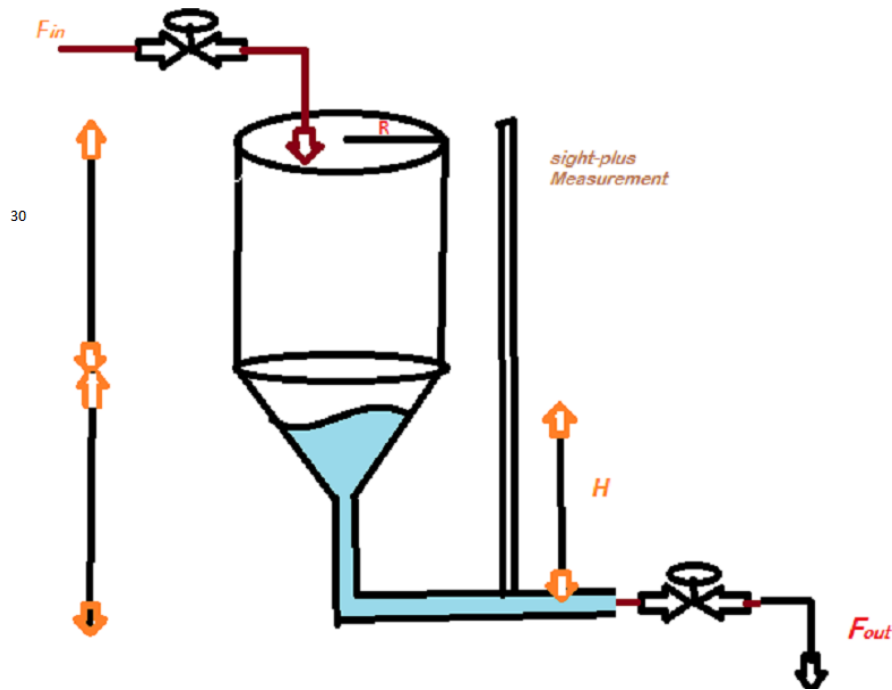


Fig 3.1. Representation figure of hopper level system

3.1.3 Modeling of cylindrical region:

Channel flow rate directly comparative to genuine root of level and hence its assignment function is given as.

$$G_{cyl}(s) = (h(s)) / (F_{in}(s)) = (k_s / (\tau s + 1)) * e^{(-t_d s)}$$

Where, A is continuous in cylinder region. It is not unpredictable based on the height h.

3.1.4 Modeling of conical region:

The Non-Linear model equation of the conical part is

$$G_{con}(s) = (h(s)) / (F(s)) = [k_s / (\tau s + 1)] * e^{(-t_d s)}$$

After Taking Linearization using partial differentiation, conical region transfer function is approximated to a first order transfer function which varies with respect to the height.

.Where;

$$K = 2\sqrt{h/b}; \quad b = a\sqrt{2g}; \quad T = 2A\sqrt{h/b}$$

K-Process Gain;

T-Time constant;

a- Bottom Outlet area;

H-Nominal level of tank;

A-Nominal area at height h;

b- Outlet discharge constant.

3.1.5 Intention conditions of the hopper tank system:

For the hopper tank system which we have taken for the study, the specifications which are considered for the real set up and the water level readings which we have taken from the hopper tank. As of the specification requirement in a pharmaceutical industrial usage according to the purpose of storage

H- Height of conical=30cm;

R- Top radius of conical=50cm;

r- Bottom outlet hole radius=20cm;

h- Nominal level of tank=30cm;

Transfer function at the nominal liquid level 30cm is,

3.2 PID tuning process:

PID controllers are probably the most regularly rummage-sale regulator arrangements in production. They do, though, at hand some important values to be needed for control and instrumentation engineering in the characteristic of varying of the gains necessary for solidity and high-quality transitory presentation. There are quite a lot of regulatory systems used in PID shift.

The stability of these belongings is realized by loop varying to construct the best possible control utility. The modification constants are given away as "K" and should be resulting for each be in charge of presentation, its depends how comeback features of the entire loop outside to the technique. They are reliant on the performance of the assessing feeler, the control valve acting as a final control element, which delays the operation of the process itself. Lower constraint values can be acting as a constants

that can regularly be initially entered with the known type of purpose, however they are on the whole distinguished, or tuned, by "bumping" the activities of process in practice by developing a setpoint change and perceiving the scheme of response.

Mainly modern manufacturing services no longer practice the tuning approach for loops to produce a useful design structure for various methods as it is determined. Using the manual design methods PID regulation and ring optimization software are worn to make sure to obtain the steady results. This software used for gathering the data which develops many process models, and recommend most favorable variation.

Calculated PID control tuning values can impulse in the arrangement and then use the forbidden system regularity response to intend the PID loop ethics. In values which can induce loops output values, which responds to the variable values with respect to period of quite a lot of transcript, calculated the loop tuning values which is optional, due to the experiment and blunder that takes place in the loops when the PID techniques are implemented by using various function. It provides an optimal range of values which sates the true possible data is obtained. the process various tuning techniques which is similar to the possible variation into the reference changes.

Another attitude analyses preliminary ethics into the Ziegler–Nichols method, and used for developing an arithmetical constraint values are considered to obtain a better tuning value for providing a better results.

Supplementary formulae were introduced for this purpose is available in existing and to tune the various parameters. This loop method allows the changing performance gauges. Many original formulae are currently surrounded inside PID tuning proposed modules having both its hardware and software parts.

Progresses in computerized PID alteration software also distribute a set of rules for regulation the proportional and integral values in a energetic or non-steady state (NSS) scenario. The system will represent the working model of a process, throughout the interruption, and compute the PID process parameter values for control of constraints in reaction.

3.2.1 Proportional term:

The main term this is said to be proportional in the parameter in design of controller. frequently provides the parameter in creating structure steadiness and successful completion of the transient response.

In calculation, the Comparative increase, K_p , gain value with respect to the proportional band:

$$PB = \frac{1}{K_p}$$

[PB is really the incomplete fault detection or the changes in the p term and it relates to various correction term taken according to the choices and it is important to identify a 100% (complete series) modification in the proportional value and maintained as output.]

Mathematically, we have:

$$\begin{aligned} K_p &= \frac{\Delta o}{\Delta e} = \frac{\text{Output Change}}{\text{Input Change}} \\ &= \frac{\Delta o / \Delta o_{\max}}{\Delta e / \Delta e_{\max}} \times \frac{\Delta o_{\max}}{\Delta e_{\max}} \\ &= \frac{1}{PB} \times \frac{\Delta o_{\max}}{\Delta e_{\max}} \leftarrow \text{This last term is usually} = 1. \\ &= \frac{1}{PB} \end{aligned}$$

In preparation PB is stated as a percentage so

$$PB\% = 100/K_p$$

3.2.2 Integrator term:

The greatest significant term in the regulator is the integrator term that states a value at pole having that $s = 0$ in the advance ring of the method. This system provides a compensation result when it attains a closed loop system in comparison with the open loop range which is said to be a type 1 process. The

reorganize instance is the process hand over with respect to the variable and its integral function is given by the integrator term which provides an output that is equal the comparative phrase yield in comeback to a change in the step values as an input to a PI controller. The integrator expression figure 3.2 as shown,

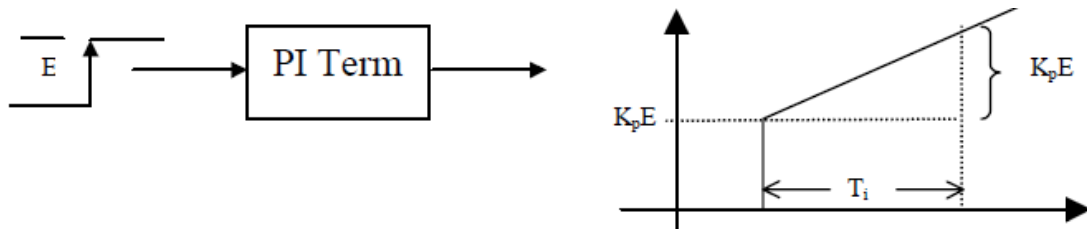


Fig: 3.2 Diagram for Integrator term

Table 3.2.1 controller type and formula

Controller Type	K_p	K_i	K_d	$C(s)$
P (Proportional)	$\neq 0$	zero	zero	K_p
I (Integral)	zero	$\neq 0$	zero	$\frac{K_i}{s}$
PI (Proportional plus Integral)	$\neq 0$	$\neq 0$	zero	$\frac{K_p s + K_i}{s} = \frac{K_p \left(s + \frac{K_i}{K_p} \right)}{s}$
PD (Proportional plus Derivative)	$\neq 0$	zero	$\neq 0$	$K_d s + K_p = K_d \left(s + \frac{K_p}{K_d} \right)$
PID (Proportional + Integral + Derivative)	$\neq 0$	$\neq 0$	$\neq 0$	$\frac{K_d s^2 + K_p s + K_i}{s}$ $= \frac{K_d \left(s^2 + \frac{K_p}{K_d} s + \frac{K_i}{K_d} \right)}{s}$

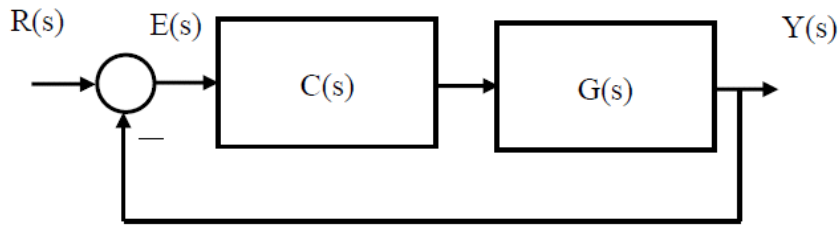


Figure 2

Fig 3.3 Block Diagram of a closed loop system:

The genuine deviation worn to be contingent based on the conditions that have to be carried out. simply imitative or integral plus unoriginal changes are approximately used.

3.3 Controller

3.3.1 PI-Proportional Integral

The observable system uses both the proportional and integral controller technique. In proportional system the error occurred is said to be an offset error which varies accordingly based on the input or servo changes. Only the integral controller cannot be used alone since it provides a integral response. Its action on the error term is due to the relational growth of the system which changes according to the time period. Its function is not possible to bring out the error value at the zero position. So in that case it is combined with proportional term to form the proportional integral control method. Due to this offset error is reduced by producing an integral overshoot. Hence it can attain a possible steady state output using this PI control method.

3.3.2 Ziegler-Nichols tuning method:

The Ziegler–Nichols or said to be a closed loop method. It is an experimental analysis technique used for tuning the various parameters like P and I.. It was introduced by an scientist known as John G. Ziegler and his partner or a methodology known as Nathaniel B. Nichols. It was started practicing in the year 1942 by applying their techniques to implement and design its parameter value. They

together worked as an employees of Taylor Instruments, described straightforward accurate measures, the two methods stated as first and second correspondingly, for fine-tuning of PI controllers.

The actions are at present known as regular for the control of process systems which is currently in practice. Both skills formulate predicted assumptions on the process representation, although it do not involve with the purpose of these representation be specifically known.

3.3.2.1The principal method:

The important technique is practical to plants with stage responses of the structure showed. This kind of reaction is exemplary of a first request framework with conveying delay, for example, that provoked by liquid stream from an evaporator along a line. It is additionally normal for a plant comprised of a progression of first request frameworks. The reaction is portrayed by two boundaries, L the postpone time and T the time consistent. These are found by attracting a digression to the progression reaction at its place of articulation and taking note of its crossing points with the time pivot and the consistent state esteem.

The plant model is accordingly

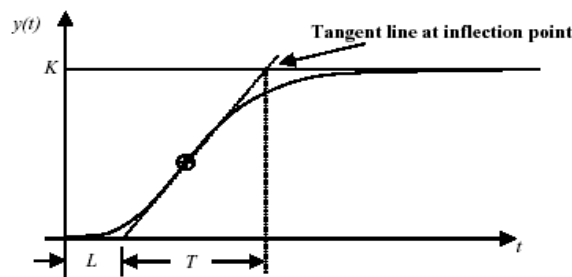


Fig 3.3.1 principle method graph

3.4 Cohen-coon tuning method

Intended for an interaction control framework to effort appropriately, its control loop(s) should be tuned, by picking the constants K_p , T_i , and T_d that will be utilized with the relative, essential, and branch activities of a regulator. With these coefficients at the

appropriate levels, the regulator can effectively and expertly manage the cycle variable to the set point. Regulator circle tuning involves the way toward sending the increases in a PID regulator so the reaction of the interaction framework is reasonable. Agreeable reaction considers wanted speed of reaction, yet meets the necessary precision and steadfastness conditions. Control measures are by and large tuned under working circumstances, as divergent to fire up circumstances; this makes the interaction variable to be steady at a working point. In the process producing, ZN-PID regulator tuning technique is normally applied, since it can undoubtedly be understood by plant administrators and is of simple solicitation. Be that as it may, this PID regulator tuning technique is ineffectual in the control of nonlinear and complex framework with changed boundaries, enormous dormancy and huge postponement, as it will in general give a higher overshoot, higher ascent time and higher settling time in the framework activity. The limitations in this ZN-PID tuning strategy could be decreased to a base level by utilizing CC-PID tuning technique to drive the framework plant. This will achieve an abatement in the framework energy ingesting to give compelling expense in the framework running.

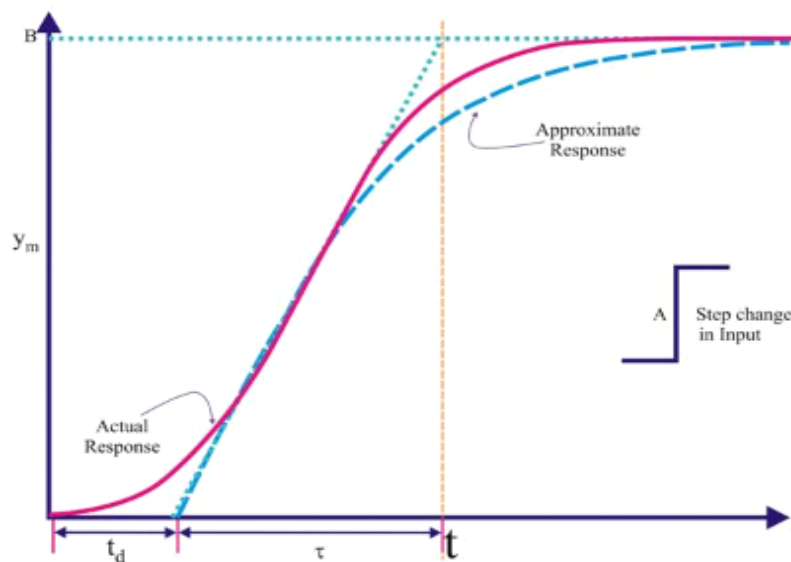


Fig 3.4.1cohen-coon method graph

3.5 Internal model control

Internal model control (IMC) modification rules have sure to be strong and benefit reasonable introduction when utilized in the control of normal cycles. In generally speaking, basic IMC tuning rules are determined for PI and PID compensators by coordinating with an inaccurate interaction model to a low-dimensional reference model. The IMC regulator structure relies upon two factors: the multifaceted nature of the model and the presentation prerequisites expressed by the originator. The IMC perspective depends on the worldwide model standard, which expresses that a criticism controller under outside unsettling influences may recover guideline and strength gave a reasonably reduplicated model of the disturbance signal is adjusted in the assessment way. At the end of the day, on the off chance that one develops the control plot dependent on a careful model of the cycle, wonderful control is hypothetically conceivable. Interior model control utilizes open-circle step-reaction Laplace move capacities with measure gain and time consistent to foresee an estimation change because of a change in setpoint. Utilization of the IMC theory can likewise create settings for standard PI or PID regulators. The calculation incorporates a model to predisposition the setpoint to eliminate the consistent state blunder, which turns into an input change strategy. One can channel the one-sided setpoint to acquire a reference direction. A solitary tuning factor channels the time consistent. High tuning factors lead to delicate control activity, though low tuning factors lead to ruinous control activity.

3.6 Shinsky tuning method

Shinsky Tuning Constant Method (STC) is generally used to control the gain of detector receivers IF amps or of low-clamor pre-intensifiers. Radars identify focuses of a wide assortment of sizes, groupings, and keen region, which produce a wide scope of reverberation signal amplitudes that may surpass the dynamic scope of a fixed addition collector. The STC-waveform can be a squared or a correct capacity of the time. Through such a thoughtfulness time control it is feasible to get the estimation of the abatement ward of the reach. Utilizing STC will in general adjust the plentifulness of echoes self-overseeing of reach.

3.6.1 Formula

The shinsky method uses the following formulas to determine its tuning method

$$K_p = K_u/2$$

$$T_i = P_u/2.2$$

CHAPTER 4

RESULT

.

The results obtained from various tuning methods are analyzed and compared to obtain the optimum value is carried out in this solution

4.1 : Ziegler—Nichols tuning

The Ziegler Nichols is a tuning method and the values of proportional and integral are shown in table and its corresponding graph is plotted using MATLAB simulink

Table 4.1 : ZIEGLER-NICHOLS TUNING

Zieler-nichols	Kp	τI
Formula	$K_c/2.2$	$\tau I = p_u/2.01$
Value	10.35	16

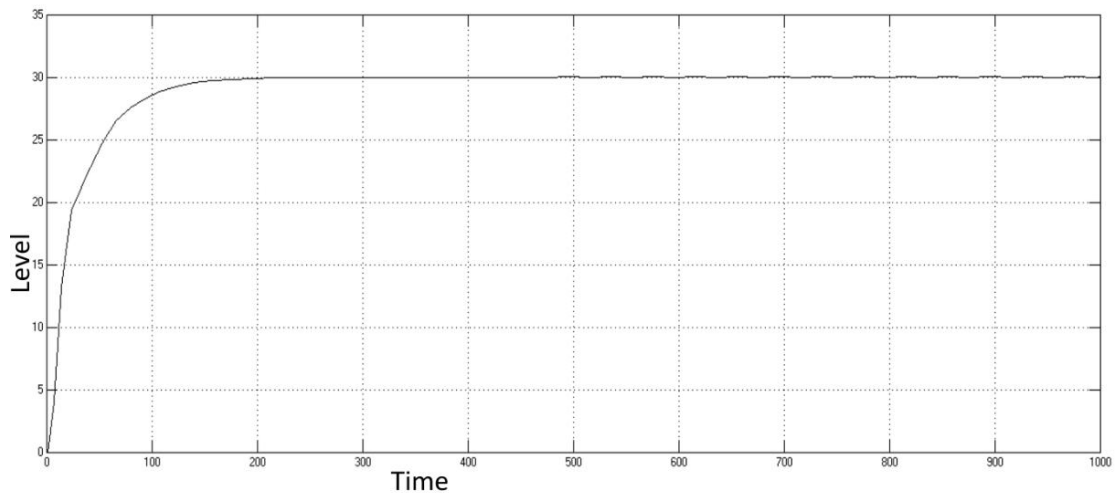


Fig 4.1.ziegler-nichols tuning rule out put

4.2Cohen-coon method

The cohen-coon is a tuning method and the values of proportional and integral are shown in table and its corresponding graph is plotted using MATLAB simulink

Table 4.2.1outputcohen-coon controller

Cohen-coon method	Kp	τ_i
Formula	$K_c=1/k\tau/td[0.9+td/12\tau]$	$\tau_i=td[(30+3td/\tau)/9+20td/\tau]$
Values	3.493	7.6

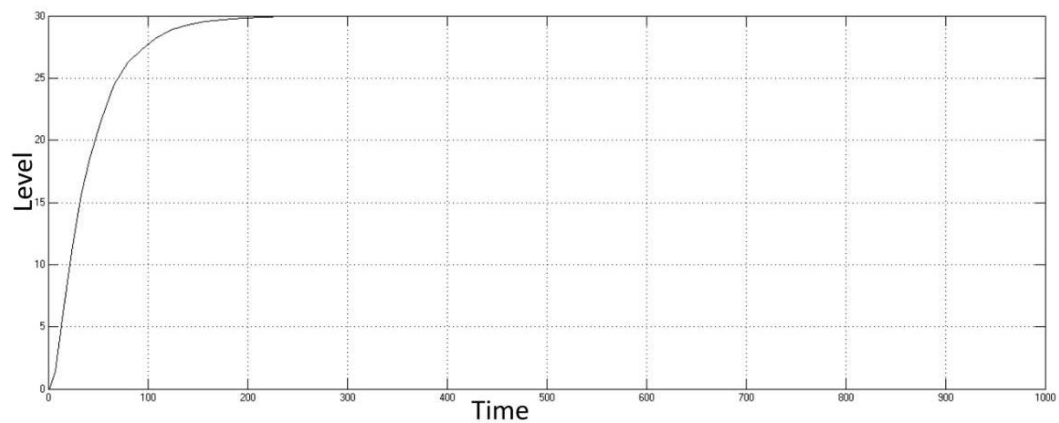


Fig 4.2.1 cohen-coon output graph

4.3 Internal model control

The Internal model control is a tuning method and the values of proportional and integral are shown in table and its corresponding graph is plotted using MATLAB simulink

Table 4.3.1 internal model control ouput

IMC	K_p	τ_i
Formula	$\tau_p/k_p\tau$	τ_i
Values	2.183	8.91

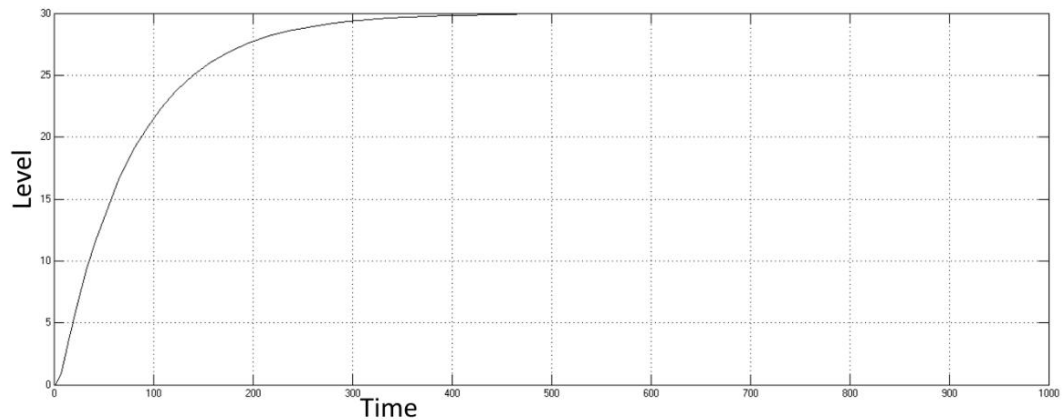


Fig 4.3.1 internal output graph

4.4 SHINSKY TUNING COSTANT METHOD

The Shisky tuning constant method is a tuning method and the values of proportional and integral are shown in table and its corresponding graph is plotted using MATLAB simulink

Table 4.4.1shinsky tuning controller out put

STC	Kp	τ_i
Formula	$K_p=ku/2$	$\tau_i=\pi v/2.2$
Values	11.38	8.7

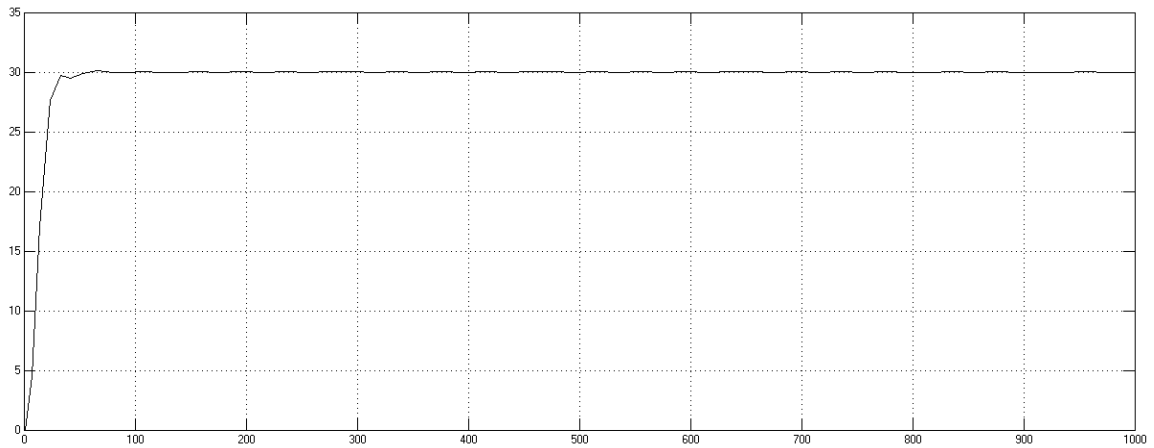


FIG 4.4.1 shinskyout put graph

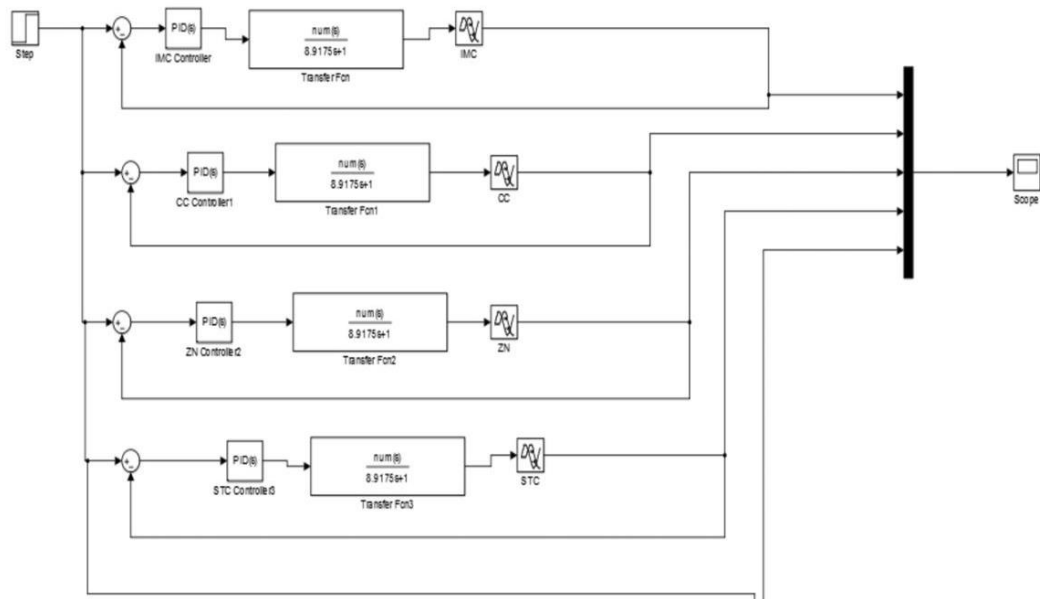


FIG 4.5.1simulink block diagram

CombinedSimulink diagram for all four controller Is determind below since STC rising time and settling time are low better when compared to other it will have better result

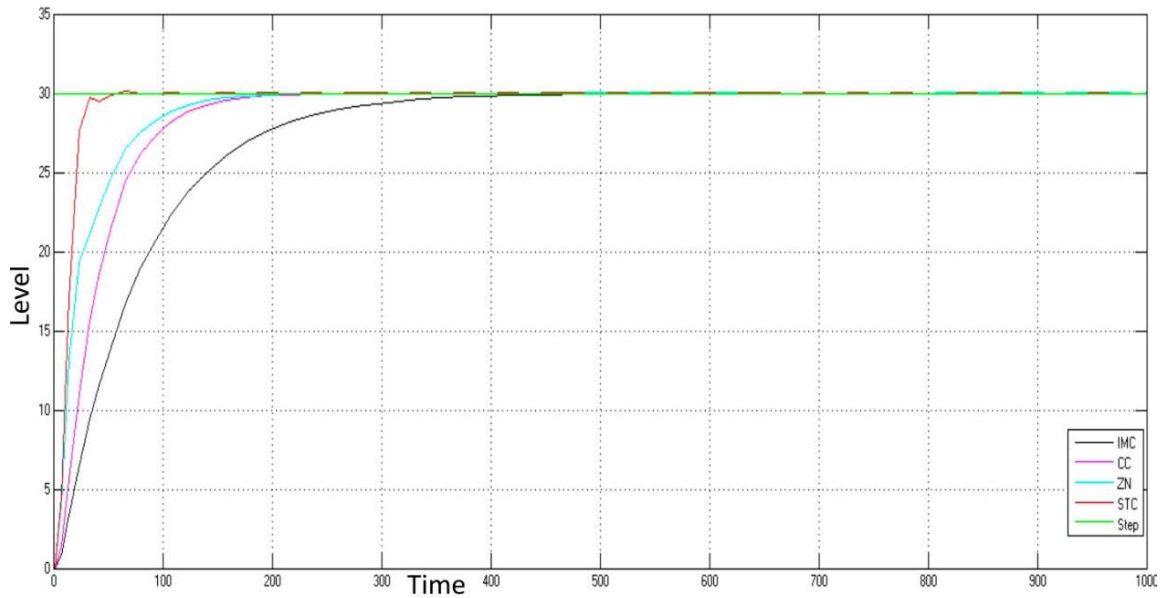


Fig 4.5.2controller out put.

Table 4.5. Performance indices

Method	Rise time	Settling time	Overshoot	peak	Peak time
Cc	352.5	382.9	0	0.7387	401
ZN	206.8	273.1	0	0.9948	401
STC	88.8	118.5	0	1.0000	401
IMC	322.7	369.5	0	0.9143	401

The table present the performance indices of various methods to analyse the performance like rise time, settling time, overshoot peak value and the peak time is represented.

- The P controller produce offset error
- The PI contrller provides overshoot
- STC has lesser rising time, settling time.
- Also STC has no overshoot.
- So STC is considered as best

CHAPTER 5

Conclusion:

The Control of Level in a nonlinear Hopper tank is a major problem without the wastage of materials used. It is achieved by using conventional and intelligentcontroller techniques like Ziegler Nicholas method, Cohen Coon method and Shinsky Tuning Constant Method,internal model control. Implementation of these techniques using controller methods like PI was developed. Comparisons are made based on the Time domain parameters and time integral performance criteria. It was analyzed from the results that Shinsky Tuning Constant Method gives better performance with minimum settling time when compared with the other conventional controllers.

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