Modeling,Simulation And Control Of Lab-Scale Process Control Trainer

Major Project Report

Submitted in partial fulfillment of the requirements

Master of Technology

In

Instrumentation and Control Engineering

By

Pooja Panchal

(13MICC14)

Department of Electrical Engineering

Institute Of Technology

Nirma University

Ahmedabad-382481

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Under the Guidance of

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May 2015

Declaration

This is to certify that

i) The thesis comprises my original work towards the degree of Master of Technology in Control and Automation Engineering at Nirma University and has not been submitted elsewhere for a degree.

ii) Due acknowledgement has been made in the text to all other material used.

Pooja Panchal

Undertaking for Originality of the Work

I, **Pooja Panchal**,Roll.No.**13MICC14**, give undertaking that the Major Project entitled " **Modeling ,Simulation and Control of Lab Scale Process Control**" submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in Instrumentation and Control Engineering (Control and Automation) of Nirma University, Ahmadabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere it will result in severe disciplinary action.

Signature of Student

Date:

Place:NU,Ahmedabad

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Certificate

This is to certify that the Major Project entitled **"Modeling, Simulation and Control of Lab-Scale Process Control Trainer"** submitted by **Pooja Panchal(13MICC14)**,towards the partial fulfillment of the requirements for the degree of **Master of Technology (Control** & **Automation Engineering)** in the field of **Instrumentation and Control** of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has reached a level required for being accepted for examination. The results embodied in this major project, to the best of our knowledge, have not been submitted to any other University or Institution for award of any degree or diploma.

Date: Place:Ahmedabad

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- Pooja Panchal

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Abstract

Process control is an engineering discipline that deals with architectures, mechanisms and algorithms to maintain various process variables at the desired value or along desired trajectory despite the presence of process uncertainties and disturbances. It is the subject area of continuous and growing interests due to its importance in accomplishing efficient and optimal (energy and production) operations across wide-spectrum of industry like oil and gas, refinery, power plant, chemical, pharmaceutical industries, cement, paper, pharmaceutical, food processing etc. The most common process variables of interest across industry are level, pressure, temperature and flow.

In this thesis, it is proposed to systematically work towards modeling, simulation, control of process variables like level, pressure control. The work will cover mathematical modeling and simulation for a single tank level system and model validation using the specific level process control trainer in our lab. Next, PID control for the same process will be developed using advanced process control instrumentation like industrial PLC (e.g. Allen-Bradley, Mitsubishi, Siemens) and NI-Lab View based SCADA platform. It is proposed to interface PLC and NI-LabView using MODBUS RTU protocol. Then, the systematic investigations will be carried out to study effects of various PID control modes and parameters on the process behaviour. Next, the work will be extended further to incorporate, test and demonstrate various PID auto-tuning techniques. Subsequently, this work can be extended further to incorporate similar studies for other process control trainers like pressure etc.

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Chapter 1

Introduction

1.1 Aim

In this thesis, the development of hardware for level and Pressure process system, with programming in CCW(Component Connected Workbench) using Structure text and a NI-LabVIEW environment has been carried out to successfully build a Low Cost SCADA system for Real Time Data Logging and Monitoring the performance of system.The main goal of this is to replace the conventional controller available on the Lab Scale Process Trainer with an advance industrial PLC.The motive behind doing this is to obtain a complete understanding of the changes in the dynamics of the system and transient response characteristics associated with the system. Mathematical model for level system is obtained for the actual system using the mass-balance formulas and the same model is validated. Using NI-LabVIEW, a SCADA platform is developed to monitor the system and log the real-time process data. Modbus RTU communication protocol is used to exchange the real-time process parameters between PLC and NI-LabVIEW. The developed setup can be used to analyze and implement advance process control algorithm like Auto tuning Using IPID block available in PLC .

1.2 Setup

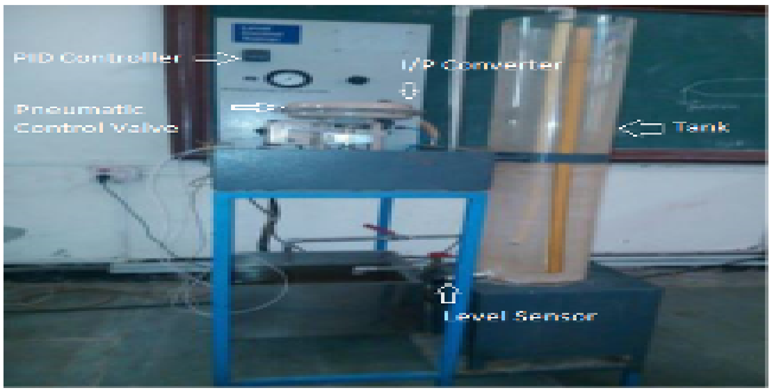


Figure 1.1: Level Trainer System

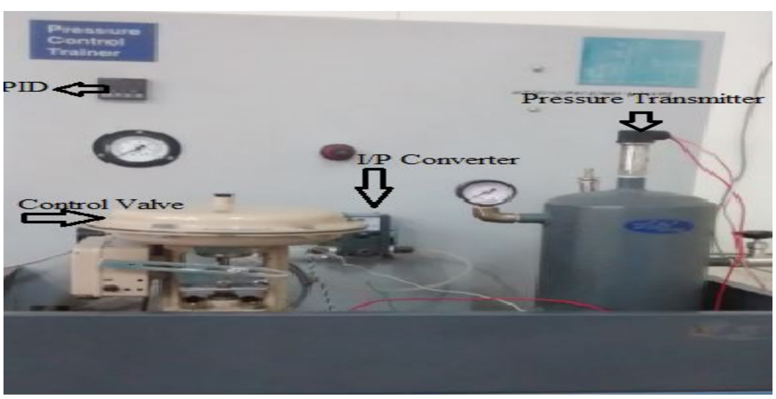


Figure 1.2: Pressure Trainer System

All the main Components are shown by the arrow in the Fig 1.1 and Fig 1.2.The system has a conventional PID controller which gives sluggish response for set point tracking. Also the PID controller offers manual tuning. Now when the process has larger effects of change in disturbance as well as in the process dynamics, it becomes quite difficult to tune the parameters manually. So the main goal is to replace the available conventional controller with an industrial Programmable Logic Controller and to control the entire level control trainer with help of that.

The transmitter is based on indirect level measurement.It works on Hydro static pressure principle.

The input to the tank is controlled by pneumatic control valve. The movement of control valve is governed by I/P converter. The Control Air Type 500X converts a current or voltage input signal to a linearly proportional pneumatic output pressure.

Chapter 2

Literature Review

Paper-1

- **Title:** Modeling and Simulation of a Level Control System
- **Detail of Conference:**Ioan Nacu1,Robin De Keyser2,Ioana Nacu1,Tudor Buzdugan1.1 Technical University of Cluj Napoca,Department of Automation,2Ghent University, EeSAdepartment of Electrical Energy,Systems and Automation.
- **Abstract:** This paper mainly focus on development of accurate model for laboratory level control system.It Based on both theoretical as well as experimental measurement.The two software(matlab and simulink)is used for simulation.
- **Conclusion:**It is not always true if the results obtained theoretically are actually applied to a real system or not. Comparing the simulation results with those measured in a real system helps us not only visualize, but also predict the process behavior
- **Comments:**The Laboratory work gives us the Knowledge to interact with real systems. This gives us the basic concepts in modeling, design and implementation of any dynamic systems.

Paper-2

- **Title:**PI and PID Auto-Tuning procedure based on simplified single parameter optimization
- **Detail of Conference:**Julio Ariel Romero, Roberto Sanchis, Pedro Balaguer Department dEnginyeria de Systemes Industrials Disseny, University JaumeI,Campus de Riu Sec,12071,Castell, Spain.
- **Abstract:**In this paper a new auto-tuning method for PI and PID controllers is proposed to minimize the load disturbance integral error by increasing the integral gain.
- **Conclusion:**In this paper, a PID auto-tuning procedure has been developed and used modified relay feedback experiments to obtain two or three points of the frequency response of the process.
- **Comments:**In this the method has been compared with other auto tuning approaches and with the optimum performance, using a batch of models widely used in the literature.

Paper-3

- **Title:**New Tuning Method for PID Controller
- **Detail of Conference:**Jing-Chung Shen Department of Automation Engineering, National Huwei Institute of Technology ,Huwei, 632,Yunlin, Taiwan.
- **Abstract:**In this paper, a tuning algorithm for PID controller is derived and For deriving the tuning formula ,one algorithm is applied that is genetic algorithm to design the PID controllers for a variety of processes. Then it correlate between the controller parameters and the parameters of the models obtained.

- **Conclusion:**A new tuning algorithm obtained for PID control of stable processes with the help of monotonic step responses . This new formula is based on genetic algorithm.

- **Comments:**In this the formula for PID controller is derived and the correlate between the controller parameter and parameter of model.

Paper-4

- **Title:**A Comparative Performance Study of PID Auto -Tuners.

- **Detail of Conference:**(1)C.C. Hang and(2) K.K. Sin.(1)PHD Degree in Control Engineering from university of Warwick.(2)Degree in Electrical Engineering from National University of Singapore.

- **Abstract:**The auto-tuning performance characteristic of three controller have been evaluated using bench test.The Controller are two commercial Single loop proportional -integral -derivative(PID) Controller,namely ,the State control Relay Feedback Auto- tuner and Foxboro Exact Self Tuning Controller and a refined Ziegler- Nicolas prototype PID controller auto tuned by means of cross- correlation method

- **Conclusion:**The approach focus on comparative Study to develop a set of benchmark test and to select a criteria to assess the performance of commercial PID auto-tuner.

- **Comments:**The main aims of this Paper are to focus on performance comparison and to introduce a method of bench mark testing.This test is further evaluate for commercial controllers

Chapter 3

Overview of Hardware and Software

This section describes the hardware used in the project as well as how to connect them with the PLC(interfacing). Hardware Included are:

- Level Trainer system
  - Level Transmitter
  - I/P Converter
  - Final Control Element: Control Valve
- Pressure Trainer system
  - Pressure Transmitter
  - I/P Converter
  - Final Control Element: Control Valve
- PLC (Allen Bradley MICRO830)
- Labview

3.1 Introduction to Level Trainer System

3.1.1 Level Sensor

The level transducer installed in the trainer kit is manufactured by ABB and its working range is - 1 to 0.25 bar.

Figure 3.1: Level Sensor

- Design and Function

  The Level transmitter works on Hydro static pressure principle which states that the force exerted by any liquid on the walls of the container in which it is placed are directly proportional to the height of the liquid.

3.1.2 I/P Converter

500X I/P Transducers Manufactured by Control Air Inc. The water inflow to the tank is maintained by a pneumatic control valve. The movement of pneumatic control valve is done by I/P converter. It converts a current or voltage input signal to a linearly proportional to output pressure[3].

- Principle of Operation

Figure 3.2: I/P Converter

It is also called as force balance device in which a coil is moving in the field of a magnet with the help of flexure.It generates the movement of the coil and flexure that is axial movement when the current flow through coil.The flexure moves near the nozzle and also developed a back pressure which is also called as a pilot pressure to an integral booster relay.Zero and Span are changed by adjusting the screws on the front face.[3]

3.1.3 Final Control Element

Samson Pneumatic Control Valve Type 241-1

- Design and principle of operation

The Type 241-1 and Type 241-7 Pneumatic Control Valves consist of a single seated Type 241 Globe Valve and either a Type 271 or Type 277 Pneumatic Actuator. In the micro-flow valve version, a micro-trim element is installed in the valve body instead of the usual seat-plug assembly.

Figure 3.3: Control Valve

Figure 3.4: Allen Bradley MICRO 830

3.2 Introduction to PLC

3.2.1 Hardware Feature

The conventional controller which is on the trainer kit is replaced by Allen Bradley micro830 PLC. The advantages of using the same can be faster response, easier programming, multi-tasking, MODBUS RTU Communication (to develop GUI in LabVIEW), inbuilt current input and output. A complete understanding of the changes in the dynamics of the system will be observed and statistics associated with it can be calculated and compared, as the modified trainer kit will have a real time data logging facility. Further to add, the developed system can be used to apply and analyze some of the well-known advance process control strategies on the system in future. AB Micro830 controllers are economical brick style controllers with the number of digital and analog inputs and outputs. It supports two to five plug-in modules and also the following communication protocols that is RS-232/RS-485 serial port as well as Modbus RTU Master and Slave, CIP Serial Client/Server and ASCII.[1]

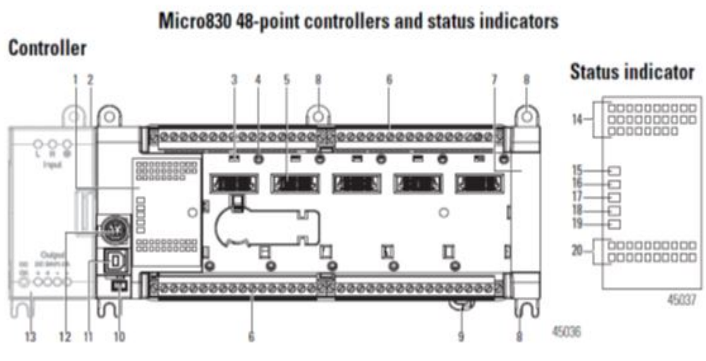


Figure 3.5: Micro830 Controller

Micro830 Controllers – Number and Type of Inputs/Outputs

Catalog Number	Inputs		Outputs			PTO Support	HSC Support
	110V AC	24V DC/V AC	Relay	24V Sink	24V Source		
2080-LC30-16QVB		10		6		1	2
2080-LC30-24QBB		14			10	2	4
2080-LC30-24QVB		14		10		2	4
2080-LC30-24QWB		14	10				4
2080-LC30-48AWB	28		20				
2080-LC30-48QBB		28			20	3	6
2080-LC30-48QVB		28		20		3	6
2080-LC30-48QWB		28	20				6

Figure 3.6: Micro 830 Input-Output

3.2.2 Programming Cables

Micro800 controllers have a USB interface, making standard programming cables.we are using a standard USB A Male to B Male cable for programming.[1]

Figure 3.7: USB Cable

3.2.3 Embedded Serial Port Wiring

It is used for short distances to devices such as HMI. For example the 1761-CBL-PM02 cable is typically used.[1]

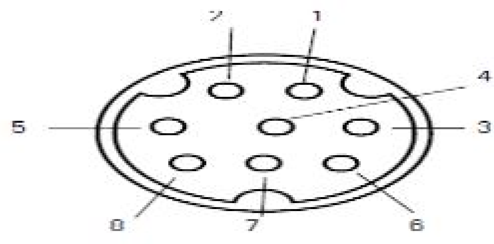


Figure 3.8: Pin Diagram

Pinout table

Pin	Definition	RS-485 Example	RS-232 Example
1	RS-485+	B(+)	(not used)
2	GND	GND	GND
3	RS-232 RTS	(not used)	RTS
4	RS-232 RxD	(not used)	RxD
5	RS-232 DCD	(not used)	DCD
6	RS-232 CTS	(not used)	CTS
7	RS-232 TxD	(not used)	TxD
8	RS-485-	A(-)	(not used)

Figure 3.9: Connection Diagram

3.2.4 Supported Communication Protocols

Micro 830/Micro 850 controllers supports three communication protocols:

- Modbus RTU Master and Slave
- CIP Serial Client/Server (RS-232 only)
- ASCII

3.3 Introduction to LABVIEW

3.3.1 LABVIEW

LABVIEW(Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language from National Instruments. Originally released for the Apple Macintosh in 1986, LabView is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms including Microsoft Windows, various versions of UNIX, Linux, and Mac OS X. The latest version of LabView is LabView 2013, released in August 2013[6].

3.3.2 GUI

In computing, graphical user interface is a type of user interface that allows users to interact with electronic devices through graphical icons and visual indicators such as secondary notation, as opposed to text-based interfaces, typed command labels or text navigation. GUIs were introduced in reaction to the perceived steep learning curve of command-line interfaces(CLI), which require commands to be typed on the keyboard[6]

3.3.3 Communication Protocol Modbus RTU

Modbus is a half-duplex, master-slave communications protocol. The Modbus network master reads and writes bits and registers. Modbus protocol allows a single master to communicate with a maximum of 247 slave devices. Micro800controllers support Modbus RTU Master and Modbus RTU Slave protocol.[7]

- An open data communication protocol
- Supplied by many SCADA and HMI software
- 2 serial transmission modes: ASCII - 10 bits RTU (Binary) - 11 bits
- Communication interface RS-232/485 and Ethernet (TCP/IP)

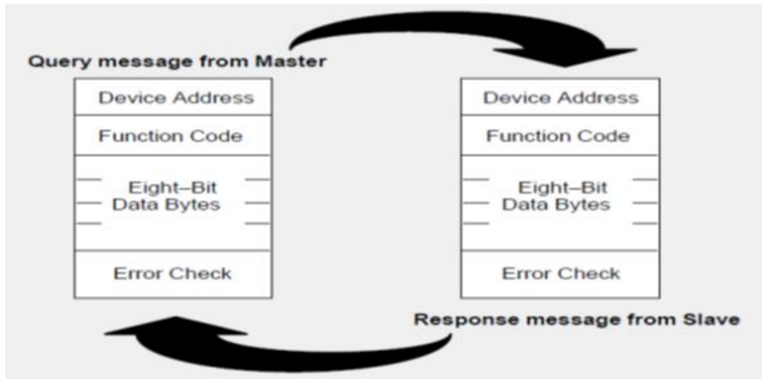


Figure 3.10: Mater Slave Querry Response

3.3.4 MasterSlave QueryResponse Cycle

3.3.5 Function of each Field of message

- Device Address: Specifies the address of the slave for communication
- Function code: In the query it tells the addressed slave device what kind of action to perform.In the response if the slave makes a normal response, the function Code in the response is an echo of the function code in the query If an error occurs the function code is modified to indicate that the response is an error response
- Data Field: In query it contain the information telling the slave which register to start at and how many registers to read. In response the data bytes contain the data collected by the slave, such as register values or status. If an error occurs data bytes contain a code that describes the error.
- The error check field provides a method for the slave to validate the integrity of the message contents.[7]

3.3.6 Transmission modes

It determines how information will be packed into the message fields and decoded.[7]

- ASCII (American Standard Code for Information Interchange)
- RTU (Remote terminal unit)

3.3.7 Transmission modes

The format for each byte in RTU mode is:

- Coding System: 8bit binary, hexadecimal 09, AF Two hexadecimal characters contained in each 8bit field of the message
- Bits per Byte: 1 start bit 8 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stops bit if parity is used; 2 bits if no parity
- Cyclical Redundancy Check (CRC)

3.3.8 List of Function code used in MODBUS Protocol

Sr.No)	**Description**
1	Status Indicator
2	Optional Power Supply Slot
3	Plug-in-latch
4	Plug in Screw Hole
5	40 Pin High Speed Connector
6	Removal I/O Terminal Block
7	Right Side Cover
8	Mounting Screw Hole
9	DIN Rail Mounting Latch
10	Mode Switch
11	Type B Connector USB Port
12	Rs-232/Rs-485 Non Isolated Combo Serial
13	Optional AC Power Supply
14	Input Status
15	Power Status
16	Run Status
17	Fault Status
18	Force Status
19	Serial Communication
20	Output Status

Table 3.1: Controller and Status Indicator Description[l]

Function Code No(hex)	**Function to Perform**
01	Read Coil Status
02	Read Input status
03	Read Holding Register
04	Read Input Register
05	Write Single Coil
06	Write Single Register
15	Write Multiple Coils
16	Write Multiple Register

Table 3.2: Function Code For Modbus Protocol

Chapter 4

System Modeling,Integration and Control

4.1 Mathematical Model of System

4.1.1 Introduction to Process

- Process:It is defined as the change in the level of liquid in the tank. The input parameter is the flow into the tank i.e. qi(t)(m3/s).
- Transducer:The transducer indirectly measures the level. So, pressure= density g head of liquid. It converts the gauge pressure to electrical current signal in (mA).
- Actuator:It takes the control signal uc(t), a current in mA and applies this to a current to pressure transducer which in turn produces a valve position,(in mm). The position of the valve stem determines the flow (in m3/s).
- Actuator Process Transducer: The liquid level system shows the liquid inflow as qi(t), and the outflow as qo(t). The height is given by h(t) and the constant cross sectional area of the tank by A.

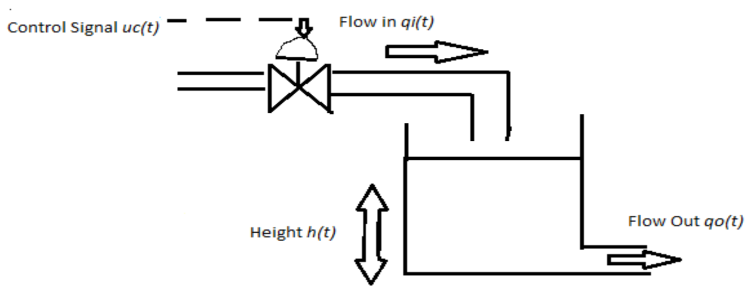


Figure 4.1: Process Block Diagram

4.1.2 Tank Modeling

The governed equation for the change in liquid volume is:

$$Rateofchangeofvolumeofliquid = inflow - outflow[8] \tag{4.1}$$

So, if the qi was equal to the qo then there would be no change in the volume of liquid which is obtained by the tank.

$$dy/dt = qi(t) - qo(t)[8] \tag{4.2}$$

We will assume 1. The cross-sectional area of the tank is constant that is A=283.39 cm2.

2. The outflow of the liquid is proportional to the height of liquid:

$$qo(t) = h(t)/R[8] \tag{4.3}$$

where R represents a parameter due to pipe restriction.

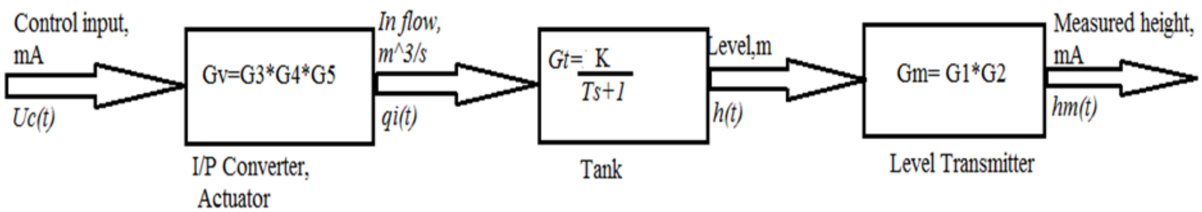


Figure 4.2: Actuator-Process-Transducer Block Diagram

Height (cm)	Time (s)	flow rate cm^3/s)	Estimated R value based on manual flow measurement (s/cm^2)	k =R (s/cm^2)	Time constant (s)
100-90	70	40.48	2.34	2.34	663
90-80	71	39.91	2.12	2.12	660
80-70	77	36.80	2.03	2.03	575
70-60	81	34.98	1.85	1.85	524
60-50	82	34.55	1.59	1.59	450
50-40	94	30.147	1.49	1.49	422
40-30	104	27.24	1.28	1.28	363
30-20	128	22.13	1.12	1.12	317
20-10	133	21.30	0.70	0.70	199
10-0	161	17.60	0.28	0.28	80

Figure 4.3: Tank Modeling Parameter

4.1.3 Transducer Modeling

The transducer indirectly measures the level. So, pressure= density g head of liquid. It converts the gauge pressure to electrical current signal in (mA). The pressure p(t), is dependent on the height of liquid h(t), above the transducer i.e. above the reference level of tank. As the level sensor is placed at the base of the tank, output of the electrical transducer is current in mA, hm (t), which represents the measurement of liquid head or height.[8]

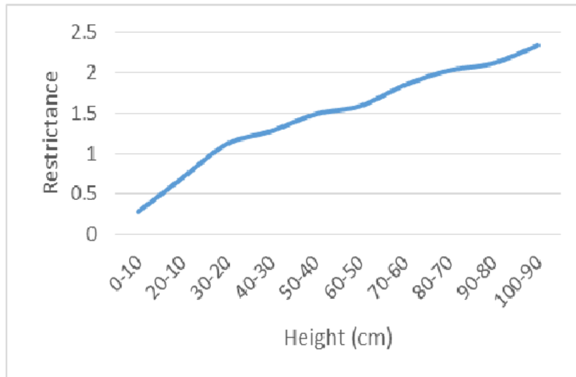


Figure 4.4: Restrictance Vs Height(cm)

For G1 Block

$$Pressure = density * gravitationalconstant * head[8] \tag{4.4}$$

$$P(t) = gh(t) = (1000kg/m^3) * (9.81) * h(t)G1 = P(t)/h(t) = 0.0981bar/m \tag{4.5}$$

For G2 Block

Maximum input range is 0.25 bar

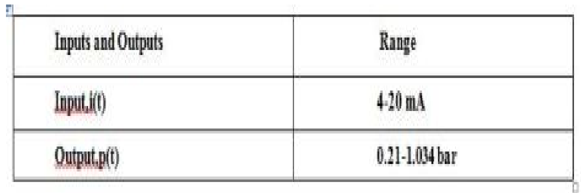
$$So, head = P(t)/g = 0.25/0.0981 = 2.55m \tag{4.6}$$

$$G2 = (20 - 4)/(0.0980 - 0) = 163.27mA/bar \tag{4.7}$$

$$Ga = G1 * G2 = 0.0981 * 163.27 = 16.08mA/m \tag{4.8}$$

4.1.4 I/P Converter

$$G3 = (1.034 - 0.206)/(20 - 4) = 0.052 bar/mA \quad (4.9)$$



Inputs and Outputs	Range
Input,i(t)	4-20 mA
Output,p(t)	0.21-1.034 bar

Figure 4.5: I/P Coverter Modeling Parameter

4.1.5 Control Valve Modeling

Stem position is in linear relationship with input pressure at valve diaphragm. Stem position=15mm,Cv=0.12,Travel=15mm

$$x(t) = G4 * p(t) \quad (4.10)$$

$$G4 = 15mm/0.828bar = 18.1mm/bar \quad (4.11)$$

$$G5 = K(Slope) \quad (4.12)$$

$$k = (0.06 - 0)/(5 - 3) = 0.0005(m^3/s/mm) \quad (4.13)$$

$$qi = G5 * x = 0.0075m^3/s/mm \quad (4.14)$$

$$Gv = G3 * G4 * G5 = 4.68 * 10^-4m^3/s/mA \quad (4.15)$$

$$k = (0.16 - 0.06)/(9 - 5) = 0.00041 \quad (4.16)$$

$$qi = G5 * x = 0.0056m^3/s/mm \quad (4.17)$$

$$Gv = 0.00034m^3/s/mA \quad (4.18)$$

4.2 Open Loop Model Validation for Level Trainer System

The fundamental activity of model validation is the comparison of predictions from a mathematical model of a system to the measured behavior of the system[12].The model which is obtained by first principle method, has to be validated. Figure 4.6 shows the open loop model validation. (The values are measured manually due to unavailability of flow sensor). The estimated restrictance value from time response nearly matches the manual Restrictance value measurement.

Height (cm)	Time (s)	flow rate (cm^3/s)	Estimated R value based on manual flow measurement (s/cm^2)	Time constant (s)	Estimated value of R from time response (s/cm^2)	Time constant from response (s)
100-90	70	40.48	2.34	663	2.39	680
90-80	71	39.91	2.12	600	1.8	510
80-70	77	36.80	2.03	575	1.76	500
70-60	81	34.98	1.85	524	1.44	400
60-50	82	34.55	1.59	450	1.41	410
50-40	94	30.147	1.49	422	1.12	320
40-30	104	27.24	1.28	363	1.02	290
30-20	128	22.13	1.12	317	0.74	210
20-10	133	21.30	0.70	199	0.56	150
10-0	161	17.60	0.28	80	0.35	100

Figure 4.6: Model Validation Parameters

4.3 Close Loop Response of the Level Trainer system

Figure 4.7 shows the closed loop response of the model found .It can be stated from the response for a step change of 1 mA in I/P converter there will be accumulation of 0.038m of level in the tank.

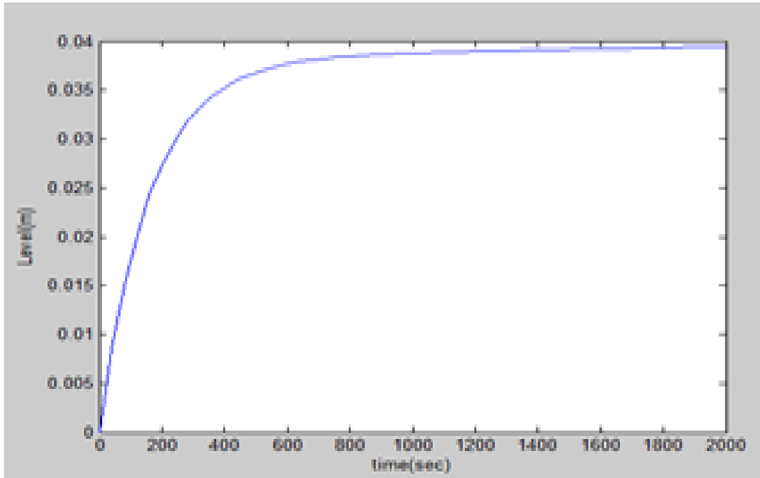


Figure 4.7: Response of liquid level to step change in input current of 1 mA.

4.4 Interfacing of components with PLC

To control the system level transmitter and I/P converter has to be interfaced with PLC. The PLC can read the level input given in terms of current by the level transmitter. Based on the control strategy, it can decide the current output given to I/P converter.

4.4.1 Level and Pressure Trainer System

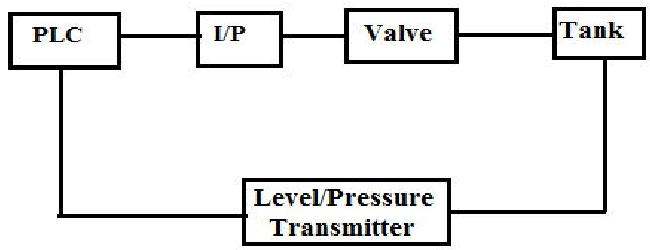


Figure 4.8: PLC interfacing block diagram

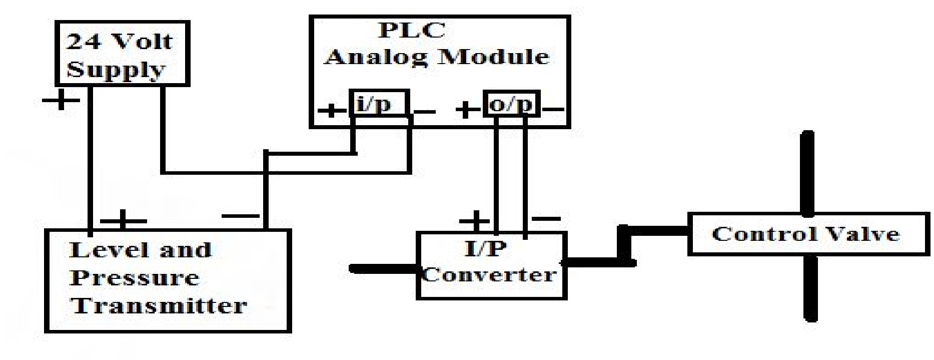


Figure 4.9: Wiring diagram

Chapter 5

PID Controller Tuning

5.0.2 Introduction

Proportional, Integral and derivative (PID) controllers are the most widely-used controller in the chemical process industries because of their simplicity, robustness and successful practical application.

Different Tuning algorithm

- Ziegler-Nichols method

  This method that is probably the most known and the most widely used method for tuning of PID controllers is also known as online or continuous cycling or ultimate gain tuning method. Having the ultimate gain and frequency (Ku and Pu) and in figure 5.1 the controller parameters can be obtained.

- Modified Ziegler-Nichols method

  For some control loops the measure of oscillation, provide by 1/4 decay ratio and the corresponding large overshoots for set point changes are undesirable therefore more conservative methods are often preferable such as modified Z-

Controller	k_c	τ_I	τ_D
P	$0.5k_{cu}$	-	-
PI	$0.45k_{cu}$	$P_u/1.2$	-
PID	$0.6k_{cu}$	$P_u/2$	$P_u/8$

Figure 5.1: Controller parameters for closed loop Ziegler-Nichols method

N settings. These modified settings that are shown in figure 5.2 are some overshoot and no overshoot.

Controller Parameters	k_c	τ_I	τ_D
Some Overshoot	$0.33K_{cu}$	$P_u/2$	$P_u/3$
No Overshoot	$0.2K_c$	$P_u/2$	$P_u/3$

Figure 5.2: Modified Ziegler-Nichols settings

- Tyreus-Luyben method

The Tyreus-Luyben procedure is quite similar to the Ziegler-Nichols method but the final controller settings are different. Also this method only proposes settings for PI and PID controllers. These settings that are based on ultimate gain and period.

- Cohen and Coon method

In this method the process reaction curve is obtained first, by an open loop test as shown in Figure 5.4, and then the process dynamics is approximated

Controller	k_c	τ_I	τ_D
PI	$k_{cu}/3.2$	$2.2P_u$	-
PID	$k_{cu}/3.2$	$2.2P_u$	$P_u/6.3$

Figure 5.3: Tyreus Luyben settings

by a first order plus dead time model, with following parameters as shown in fig.

Controller	k_c	τ_I	τ_D
P	$\frac{1}{K_m}\cdot\frac{\tau_m}{d}$	-	-
PI	$\frac{0.9}{Km}\cdot\frac{\tau_m}{d}$	$\frac{d}{0.3}$	-
PID	$\frac{1.2}{Km}\cdot\frac{\tau_{pn}}{d}$	2d	0.5d

Figure 5.4: Cohen Coon settings

Auto tuning Methods

The auto tuning concept will be implemented using IPID Controller function block available in Component Connected Workbench instruction set,is based on PID control theory and combines all of the necessary logics to perform analog input channel processing and proportional-integral-derivative control.

To run an auto tune sequence we have to follow these many steps.

- Set the input initialize to TRUE.
- Set the input Auto tune to TRUE.
- Set the input initialize to FALSE.

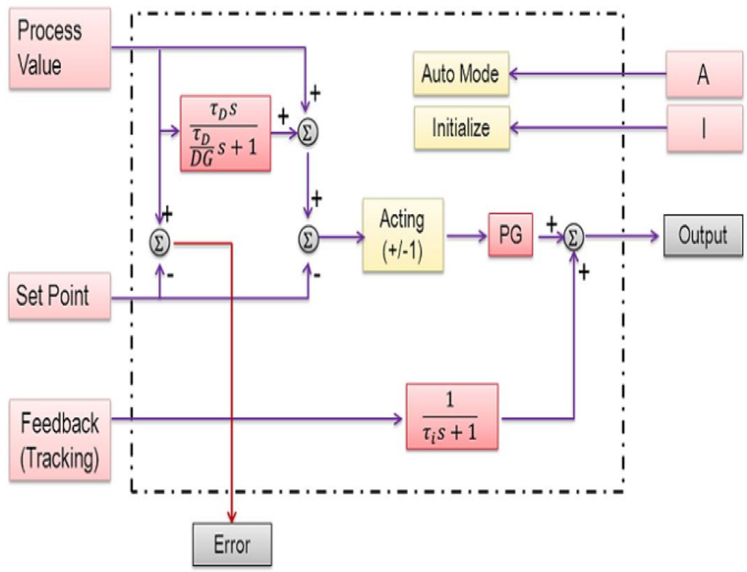


Figure 5.5: IPID Functional Block Diagram

- Wait until the output ATWarning changes to 2.
- Transfer the values for the outgain to inputgain.

5.1 Controller Tuning for Level system

5.1.1 Results for Level system

Using the Ziegler Nicholas method based (S-curve method) on the step response of the plant, the values of PI parameters were obtained for level trainer system as Kp=20 and Ki=0.0009.we can say that increasing Kp will improve the speed of response but increasing it after a fixed point (which may differ for different process) will make the controller behave just as the proportional controller and to remove the problem of overshoot we made the algorithm in such a way that the integral term will come into action only when the error is in particular range so this has remove the problem of integral windup and hence the problem of overshoot. We have tried to match the tuning parameters with that obtained from the response of the model. Now, for the single tank level system we obtain different model for different range of level. But as the model does not involve changing system dynamics, the tuned PID parameter with respect to model will not be accurate for the actual system.so we have made some assumptions and then correlate with that to real system. Also while tuning PID in the case of actual system, we have considered two conditions, one is without any load disturbance and with static load disturbance. For both the conditions graphs were obtained and are shown below in figure 5.6,5.7,5.8,5.9,5.10.Analysis given in figure 5.11,5.12.

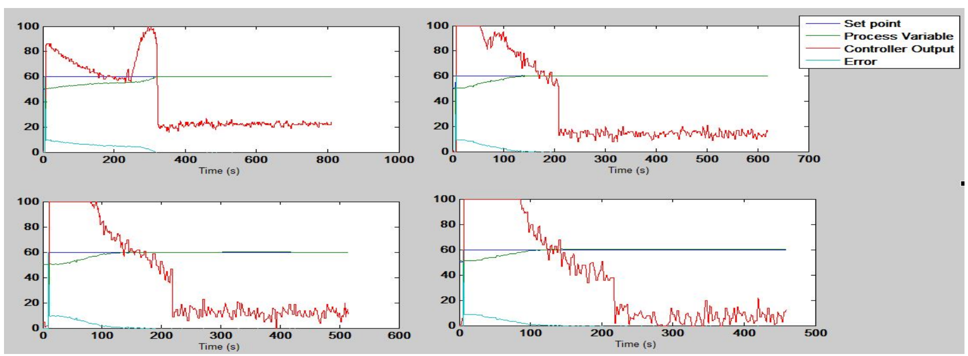


Figure 5.6: Close loop time response when (a) Kp=5,Ki=0.0009, (b) Kp=10, Ki=0.0009, (c) Kp=15, Ki=0.0009 (d) Kp=20, Ki=0.0009

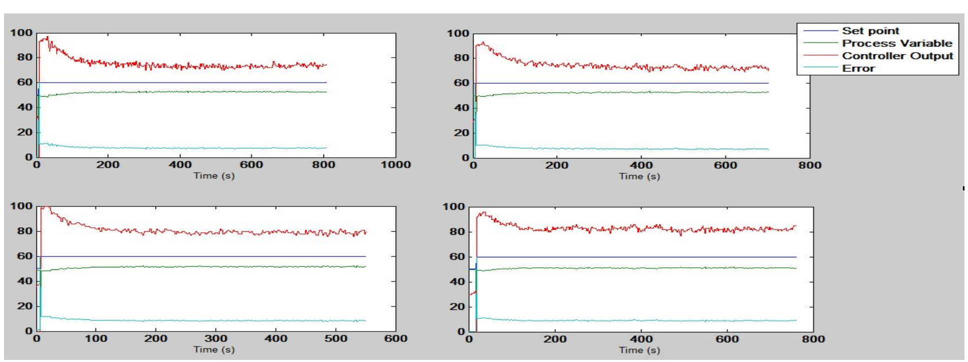


Figure 5.7: Close loop response for different load condition when Kp=5 Vs Time(sec)

- Analysis with no load disturbance

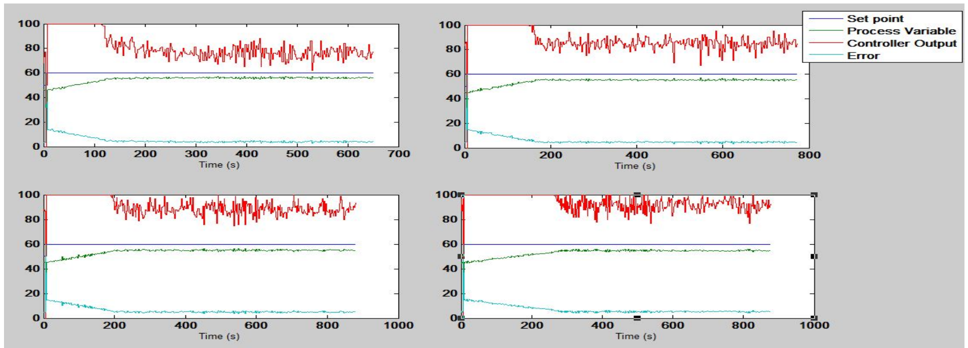


Figure 5.8: Close loop response for different load condition when Kp=10 Vs Time(sec)

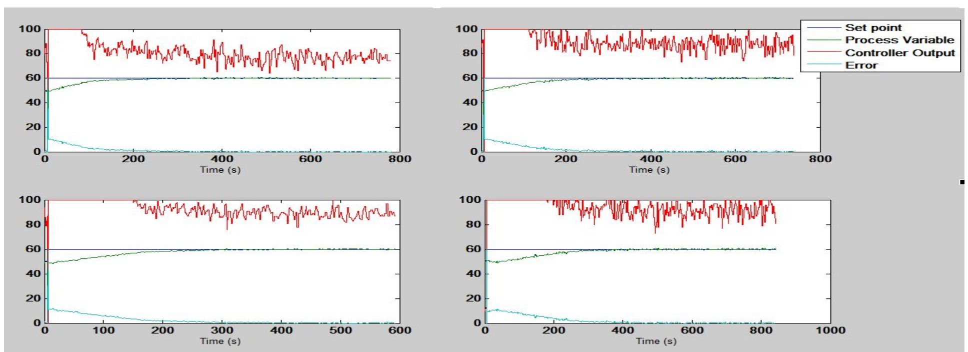


Figure 5.9: Close loop response for different load condition when Kp=15 Vs Time(sec)

Figure 5.11 shows values of settling time and time constant for different values of PI parameters when setpoint is 50.

- Analysis with static load disturbance

Fig 5.12 shows values time constant and setting time for different valve openings.

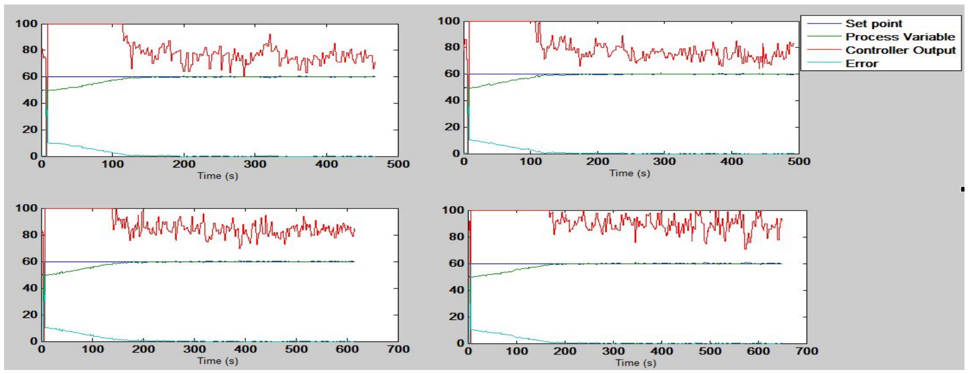


Figure 5.10: Close loop response for different load condition when Kp=20 Vs Time(sec)

Sr. No.	PID Tuning Parameters	Settling Time (sec)	Time Constant (sec)
1	Kp=5, Ki=0.0009	800	290
2	Kp=10, Ki=0.0009	600	320
3	Kp=15, Ki=0.0009	525	250
4	Kp=20, Ki=0.0009	410	215

Figure 5.11: Settling time and Time constant for different values of PI parameters when setpoint is 50.

5.2 Controller tuning for Pressure system

5.2.1 Results for Pressure Trainer System

Using different tuning method, the values of PI parameters were obtained for pressure trainer system as Kp=20 and Ki=0.0009(Good gain method),Ki=50,Ki=0.004(Zigler nicolas method),Ki=33,ki=0.009(Modified zigler nicolas and Ki=32,ki=0.0009(Lubyen and Cohen coon method).we can say that increasing Kp will improve the speed of response but increasing it after a fixed point (which may differ for different process) will make the controller behave just as the proportional controller and to remove the problem of overshoot we made the algorithm in such a way that the integral

Sr. No	PID Tuning Parameters	Valve Opening in %	Settlingtime in seconds	Time constant in seconds
1	Kp=20 Ki=0.C009	25	180	60
2		50	230	70
3		75	285	125
4		100	320	130
5	Kp=15 Ki=0.C005	25	250	50
6		50	260	65
7		75	290	80
8		100	300	95

Figure 5.12: Time constant and setting time for different valve openings

term will come into action only when the error is in particular range so this has remove the problem of integral windup and hence the problem of overshoot.Also while tuning PID in the case of actual system, we have considered two conditions, one is without any load disturbance and with static load disturbance. For both the conditions graphs were obtained and are shown below in figure 5.13,5.14,5.15,5.16,5.17.

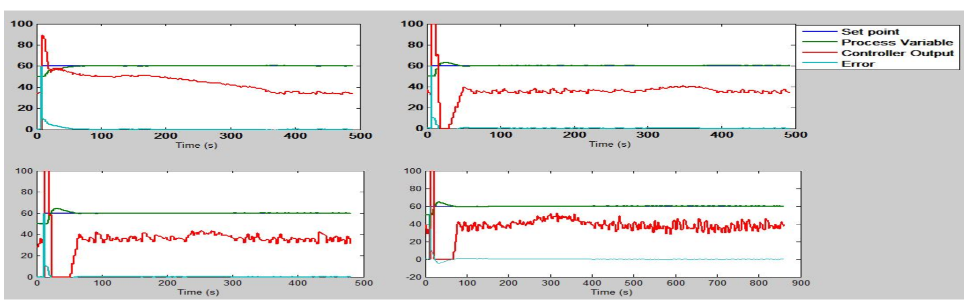


Figure 5.13: Close loop time response when (a) Kp=5,Ki=0.0009, (b) Kp=10, Ki=0.0009, (c) Kp=20, Ki=0.0009 (d) Kp=32, Ki=0.0009

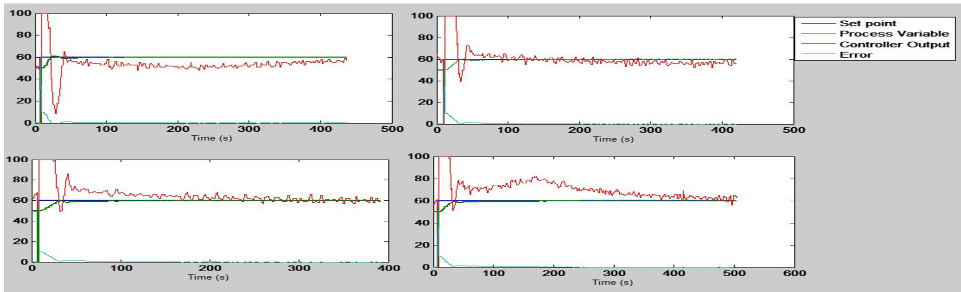


Figure 5.14: Close loop response for different load condition when Kp=20,ki=0.0009 Vs Time(sec)

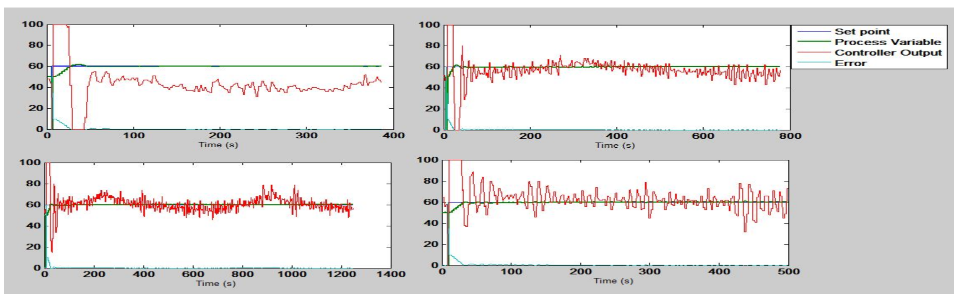


Figure 5.15: Close loop response for different load condition when Kp=32,ki=0.0009 Vs Time(sec)

5.2.2 Auto tune Results for Pressure Trainer System

SR.NO	PID Tuning Parameters	Settling Time(sec)	Time Constant(sec)
1	Kp=5,Ki=0.0009	90	30
2	Kp=10,Ki=0.0009	60	25
3	Kp=15,Ki=0.0009	50	20
4	Kp=20,Ki=0.0009	40	10

Figure 5.16: Analysis with no load disturbance

SR No	PID Tuning Parameters	Valve Opening in %	Settling Time in seconds
1	Kp=20 Ki=0.0009	25	40
2		50	68
3		75	75
4		100	80
5	Kp=32 Ki=0.0009	25	38
6		50	40
7		75	41
8		100	50

Figure 5.17: Analysis with Static load disturbance

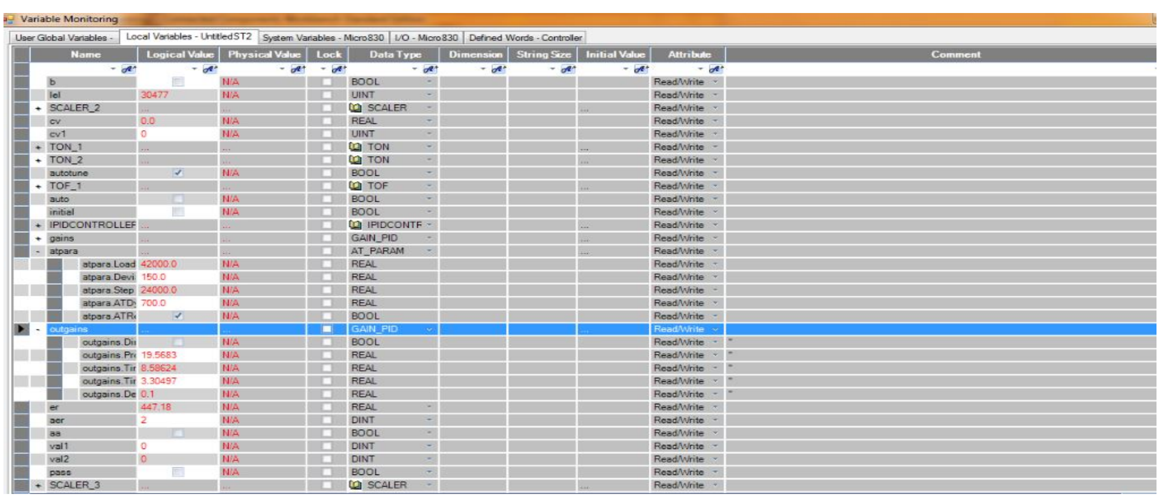


Figure 5.18: Auto tune Response when Kp=19.5,Ki=0.0008 in Variable Monitoring

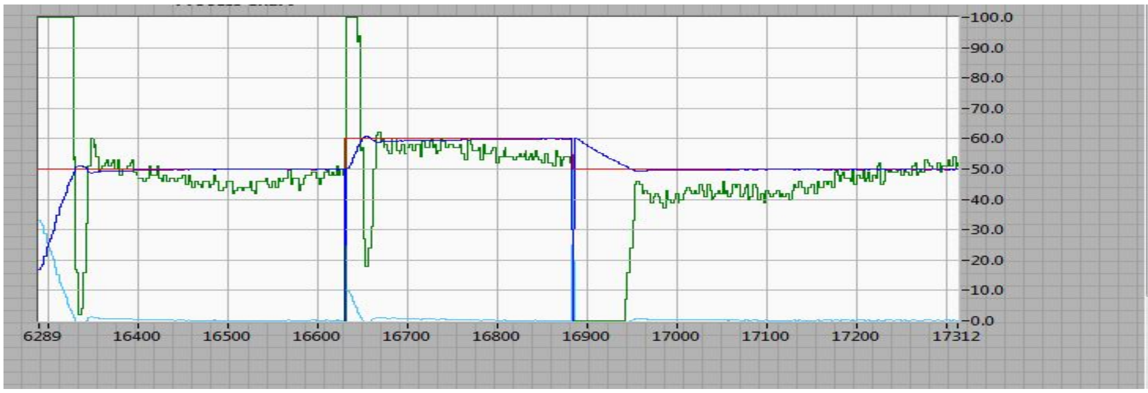


Figure 5.19: Auto tune Response when Kp=19.5,Ki=0.0008 Vs time(sec).

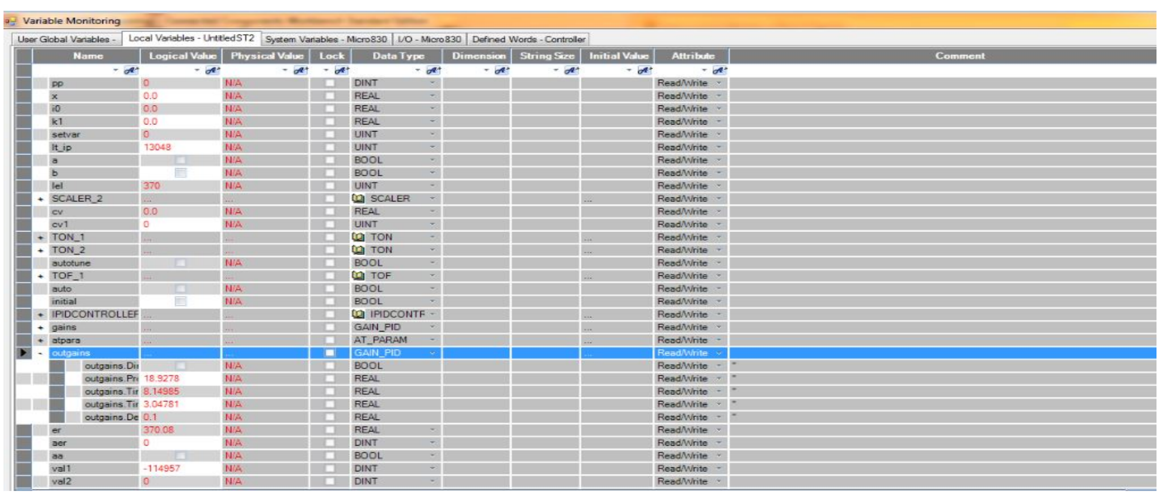


Figure 5.20: Auto tune Response when Kp=18.9,Ki=0.0008 in Variable Monitoring

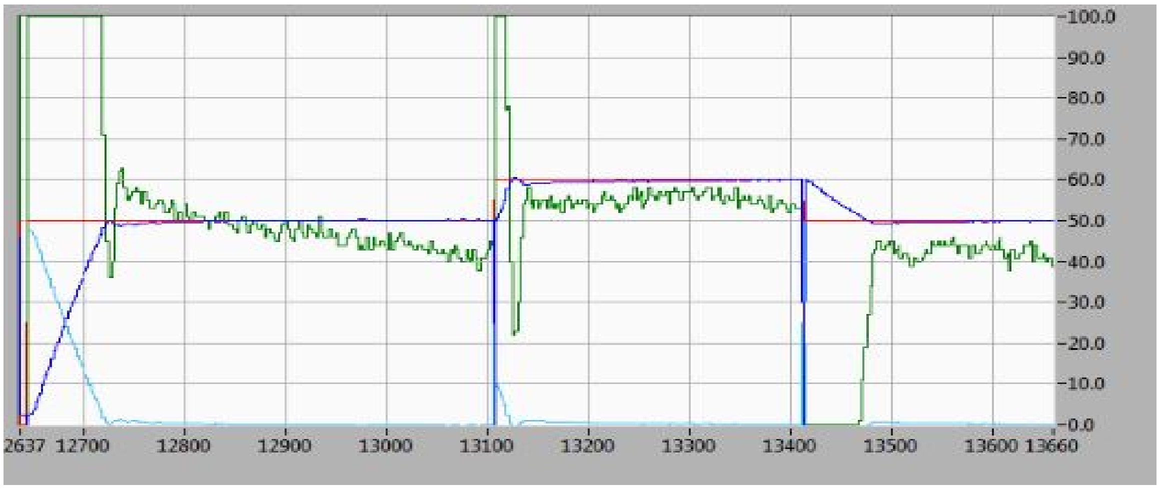


Figure 5.21: Auto tune Response when Kp=19.5,Ki=0.008 Vs time(sec)

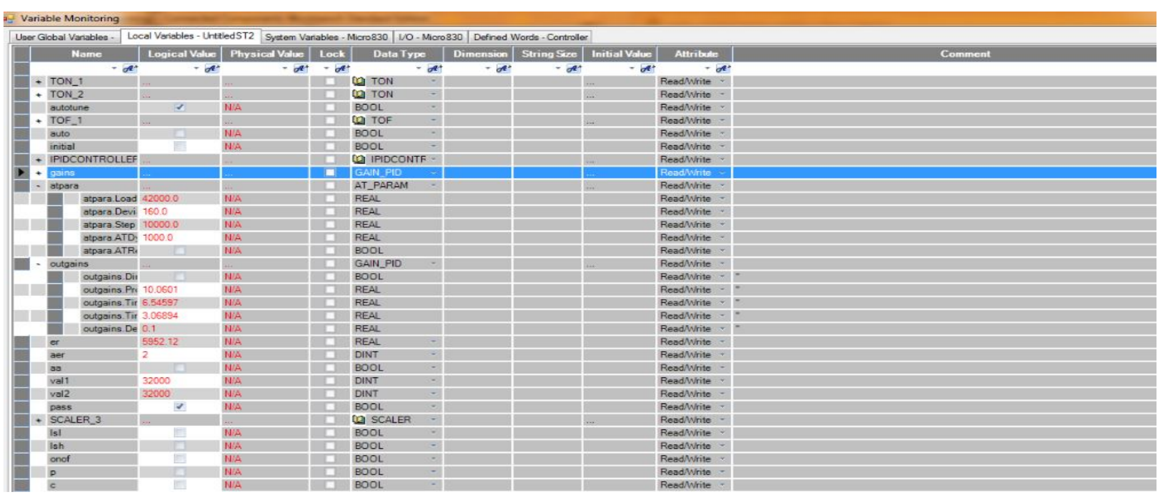


Figure 5.22: Auto tune Response when Kp=10,Ki=0.007 in Variable Monitoring

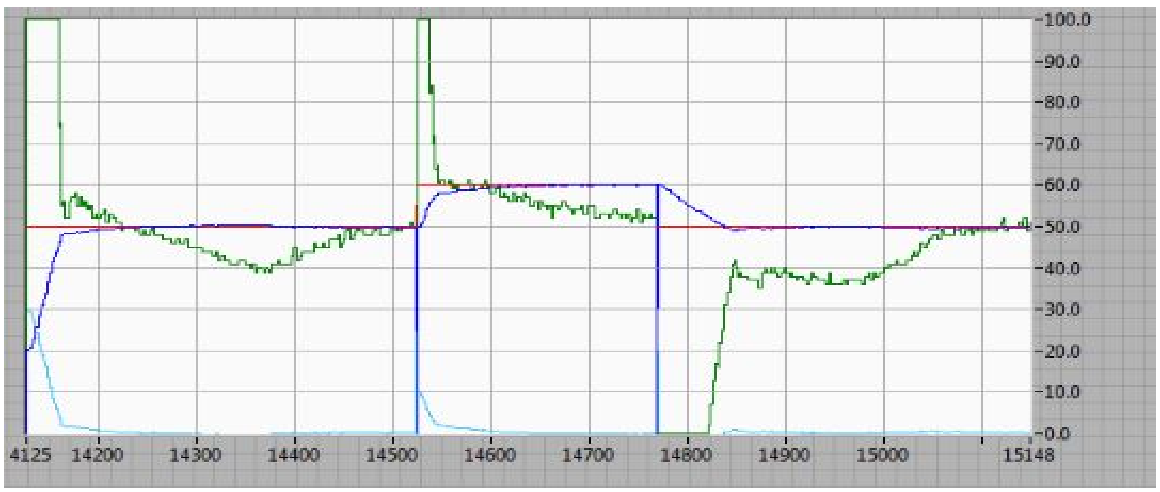


Figure 5.23: Auto tune Response when Kp=10,Ki=0.007 Vs time(sec)

Chapter 6

NI-LabVIEW Based Scada For Level and Pressure Trainer System

A GUI designed in LabVIEW makes the real time monitoring as well as data logging possible. Figure 6.1 shows the block diagram of the developed SCADA in LabVIEW. Figure 6.2 shows the front panel of the developed SCADA in LabVIEW.

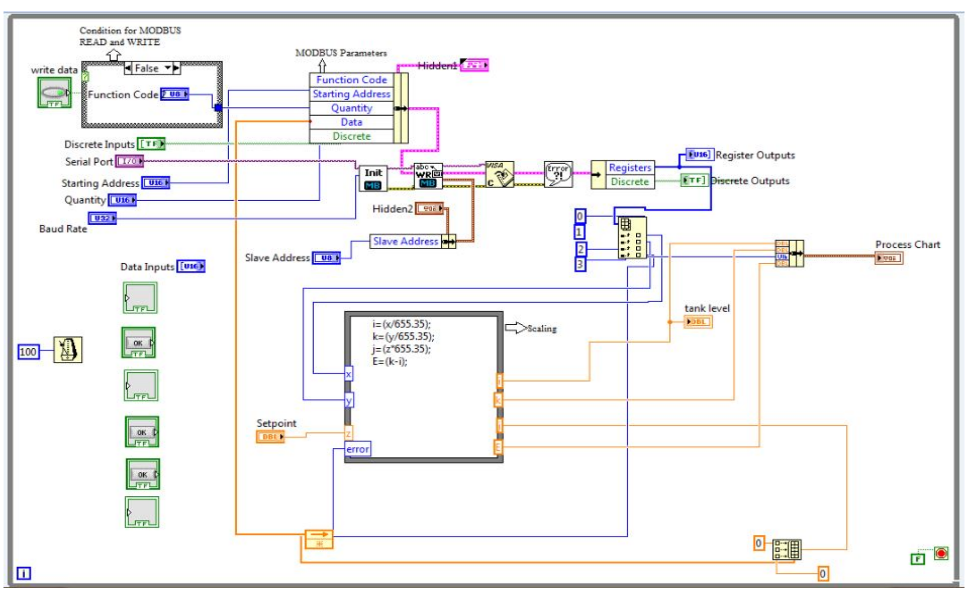


Figure 6.1: Block Diagram of Level Trainer System

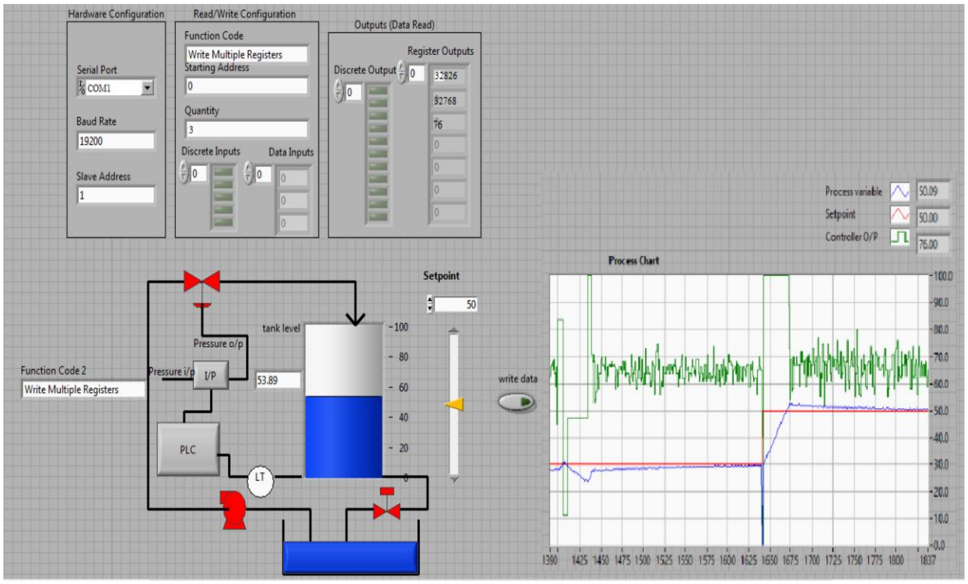


Figure 6.2: Front panel of Level Trainer System

Chapter 7

Concluding Remark and Future Scope

7.1 Concluding Remark

Thus a low cost SCADA platform for level and Pressure control trainer system was developed using MODBUS RTU communication protocol between NI-LabVIEW and AB MICRO 830 PLC. The developed platform enables the user to visualize real-time process trend. Some other features of SCADA like data logging, remote control, historical trend etc. can be incorporated easily into the system. Mathematical model based on the mass balance principal for the level system was formulated. From the figure it is observed that the values of outflow restrictance and time constant obtained in the model validation are nearly matching the values formulated in the model. Applying the obtained PI values Kp=20 and ki=0.009 for level system and for pressure Kp=33,K=0.009,gives satisfactory response in both the cases i.e. with and without load disturbance.The auto tune result also gives satisfactory response as compare it with different tuning algorithm.

Now to remove the problem of overshoot we made our algorithm in such a way that the integral term will come into action only when the error is in particular range so this has remove the problem of integral windup and hence the problem of overshoot.

7.2 Future Scope

- Interfacing of Flow trainer system.
- Implementation of Advance control scheme for Level system eg.MPC,IMC.

7.3 References

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