Abstract

In this proposed project it is to work toward modeling, simulation and control of process variable like temperature with large time delay. The project includes system identification and control of temperature system with variable time delay. A physical model will be developed which exhibits variable time delay. By running system in open loop System Identification will be carried out on platform like MATLAB. Next part is to develop PID controller for the temperature system without time delay on platforms like NI-LabVIEW. Then implementation of same PID controller settings on temperature system with time delay will be carried out. After successful implementation of PID controller on both system comparative analysis will be done to check whether PID controller gives satisfactory results or not. The next step is to develop Smith Predictor in NI LabVIEW and simulation would be carried on each model and comparative analysis would be done. PLC (Backhoff EK-1100) will be use as data acquisition i.e. it will acquire data from sensor and drive the actuator accordingly. Comparative analysis will be done between two controllers and depending upon the results conclusion would be drawn.

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Chapter 1

Introduction

In automation industries many process shows time delay in their dynamic behavior. Presence of dead time or time delay in any process is unwanted and thus controlling such processes is serious challenge since it makes the process sluggish and unstable. This project is designed to monitor and control the temperature of system with variable time delay. This project can be categorized into four main parts. The first part deals with installation and configuration of Backhoff PLCs input and output modules and its interface with TwinCAT and NI-LabVIEW. The second part of the project deals with System Identification of the temperature system on platform like MATLAB. The third section involves implementation on PID controller in NI-LabVIEW for the system with and without large time delay and then investigation of PID controller performance on both system and conclude suitable result. The final part of the project deals with implementation of Smith Predictor for temperature system with variable time delay on platform like NI-LabVIEW and simulation will be carried out. Finally comparative analysis of both the controller would be done.

1.1 Dead Time

Dead time is the delay between the application of a controller's output and its first effect on the process variable. During this interval, the process does not respond to the controller's activity, and any attempt to manipulate the process variable before the dead time fails. The cause of dead time can be, it takes time for the material to travel from one point to another, sensors and analyzers takes times to produce output, some control loops have sample and hold instrumentation resulting in small time delay or approximating higher order systems into first order with dead time FOPDT for ease in controller tuning and design

1.2 System Identification

System identification is a method of using the input and output data of the system to build the mathematical model of the system, which is being widely applied to various fields of production and life.

Traditional methods of Linear System Identification includes linear system identification and nonlinear system identification. The traditional identification methods are based on determining the system model framework and the error criterion function, and then according to input and output data of the system, the model parameters are determined by minimizing the error criterion function. Traditional identification methods include least squares method, gradient correction method and maximum likelihood method and so on

Modern methods of Non Linear system identification There have been many modern methods for nonlinear system identification based on the neural networks, fuzzy logic, genetic algorithm, auxiliary model identification algorithm, multi-innovation identification algorithm and hierarchical identification algorithm.

1.3 PID

A Proportional Integral Derivative Controller is a control loop feedback mechanism normally used in industrial control systems. A PID controller continuously calculates an error value produced by difference between the measured process variable and desired set point. The controller attempts to minimize the error by adjusting the controlled variable such as the position of control valve.

$$u(t) = Kpe(t) + Ki \int_0^t e(T)dt + Kd\frac{de}{dt}$$

Where Kp,Ki,Kd denotes the coefficient for the proportional, integral and derivative terms respectively. In PID the proportional controller reduces the rise time but does not eliminate the steady state error. An integral controller will eliminate the steady state error for step change in input but it reduces the transient response. The derivative controller will increase the stability of system and improves the transient response and reduce the overshoot

1.4 Smith Predictor

Smith predictor algorithm is the dead time compensation. The technique is a model based approach to better control of system with long dead times. Smith predictor can be divided into two parts namely the primary Gc(s) controller and predictor part. This algorithm is primarily designed for continuous time PID controller[1].

1.5 Model Predictive Control (MPC)

Model Predictive control is an advanced process control method used in process industries like chemical plant and oil refineries. The basic concept of MPC is to use a dynamic model to forecast system behavior,and optimize the forecast to produce the best decision the control move at the current time. It has the ability to anticipate the future events and take control actions accordingly. PID controllers do not have this predictive ability.

1.6 Block Diagram

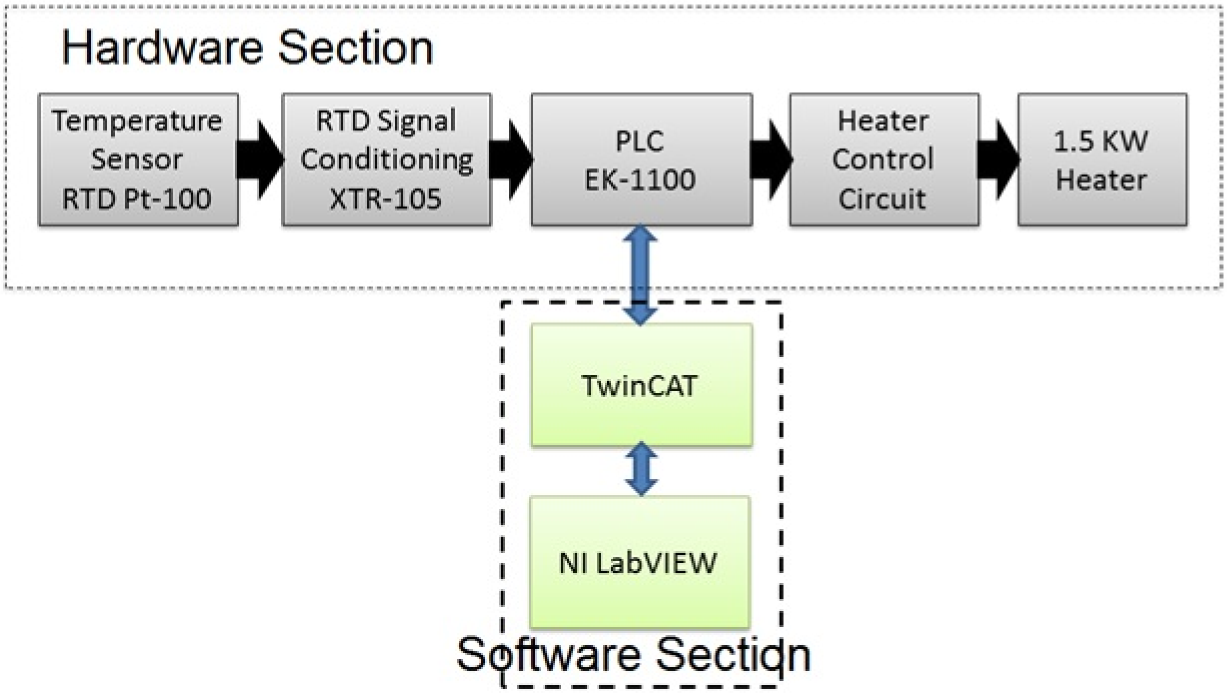


Figure 1.1: Block Diagram

Sensor used to measure the temperature was RTD Pt-100. A signal conditioning circuit was designed to give output in the range of 1-5V. The output of signal conditioning circuit was then given to PLCs analog input (EL-3162) and the temperature was displayed on TwinCAT software by scaling input 1-5V to corresponding 0-100 C. TwinCAT software was integrated with 3rd party software like NI LabVIEW 2013 and all the control algorithms were developed on NI LabVIEW platform. Controller output from LabVIEW was then given to PLCs Analog Output (EL-4002) via TwinCAT software. Output from the analog module was then given to heater control circuit. Depending upon output from analog module i.e 0-5V equivalent PWM is generated and heater is operated accordingly i.e. at 0V heater is completely ON (100 % duty cycle) and at 5V heater turns OFF (0% duty cycle).

Chapter 2

Literature Survey

2.1 Title: The Research Survey of System Identification Method

2.1.1 Authors

Li Fu, Pengfei Li

2.1.2 Abstract

At present, as a method of establishing mathematical model of the system, the system identification has been widely applied to the automatic control, aviation, spaceflight,astronomy, medicine, biology, marine ecology and society,economics and many other fields. With the rapid development of science and technology, the status of system identification technique in various disciplines is becoming increasingly important. This paper firstly introduces traditional methods of linear system identification, and then modern methods of nonlinear system identification are introduced briefly based on the neural network, fuzzy logic, genetic algorithm, swarm intelligence optimization algorithms, auxiliary model identification algorithm, multi-innovation identification algorithm and hierarchical identification algorithm, and finally the author analyses the developing tendency and prospect of

2.1.3 Conclusion

The author, from the different definitions of system identification, reviews the traditional and modern methods of system identification, and then analyzes the difficulties and prospects of system identification, in hopes of bringing benefits to related researchers and engineers.

2.2 Title: Modeling and simulation of temperature control system

2.2.1 Authors

Ioan Nascu, Robin De Keyser, Ioana Nascu, Tudor Buzdugan

2.2.2 Abstract

This paper describes a methodology for developing an accurate model of a laboratory level control system (Festo Compact Workstation). The model of each element in the system is based on the theoretical background of the functionality as well as on experimental measurements. Scientific software (Matlab and Simulink) is used to aid the simulation activities. A suggested model is presented and the simulations that may be put in practice provide students with important concepts regarding the analysis of continuous dynamic systems.

2.2.3 Conclusion

It is not always true if the result is obtained theoretically are accurately applied to real system or not comparing the simulation result with those measured in the real system helps us not only visualize but predicts the process behavior

2.3 Title:PI and PID auto-tuning procedure based on simplified single parameter optimization

2.3.1 Authors

Julio Ariel Romero, Roberto Sanchis, Pedro Balaguer

2.3.2 Abstract

In this paper a new auto-tuning algorithm for PI and PID controllers based on relay experiments is proposed to minimize the load disturbance integral error (IE) by maximizing the integral gain, subject to a desired phase margin, and a minimum required gain margin constraint. The main advantage of the proposed auto-tuning algorithm with respect to previous works is that it leads, for most of the processes, to PID tuning with close loop performance similar to PID designed using off-line numerical optimization. Moreover the algorithm is applicable to any linear model structure, including dead time and non-minimum phase systems.

2.3.3 Conclusion

A new tuning algorithm obtained for pid control of stable processes with the help of monotonic step response. This new formula is based on genetic algorithm

2.4 Title:Comparison of PID Controller and Smith Predictor Controller for Heat Exchanger

2.4.1 Authors

V.Jenifer Poorani, L.D.Vijay Anand

2.4.2 Abstract

Smith Predictor control is theoretically a good solution to the problem of controlling the time delay systems. Heat Exchangers are widely used in Chemical Industries. The controlled system is a tubular heat exchanger, in which the cold water is heated by hot water and it is a nonlinear system with time delay. The Smith predictor is used for control of the heat exchanger. Smith predictor is an effective control of thermal process can lead to energy savings. This Paper provides an overview of performance conventional PID controller and Smith predictor. It is difficult to tune the parameters and get satisfied control characteristics by using normal conventional PID controller. As the smith predictor has the ability to satisfied control characteristics and it is easy to computing. The experimental results verify that a smith predictor controller has better performance than the PID controller. The simulation of smith predictor for heat exchanger has been done using the software package MATLAB/SIMULINK.

2.4.3 Conclusion

Smith Predictor was applied to co current heat exchanger. P,PI and PID controllers are implemented and compared with Smith Predictor. It was proved that conventional controllers did not gave satisfactory results as compared to smith predictors which gave good response.

Chapter 3

Hardware Configuration

3.1 Backhoff PLC (EK1100)

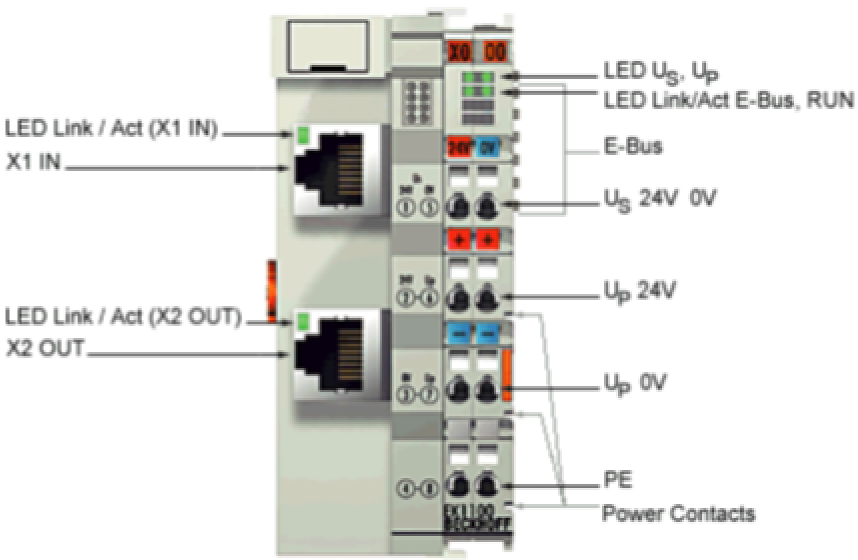


Figure 3.1: EK-1100.

3.2 I/O Modules

3.2.1 Digital input module (EL1008)

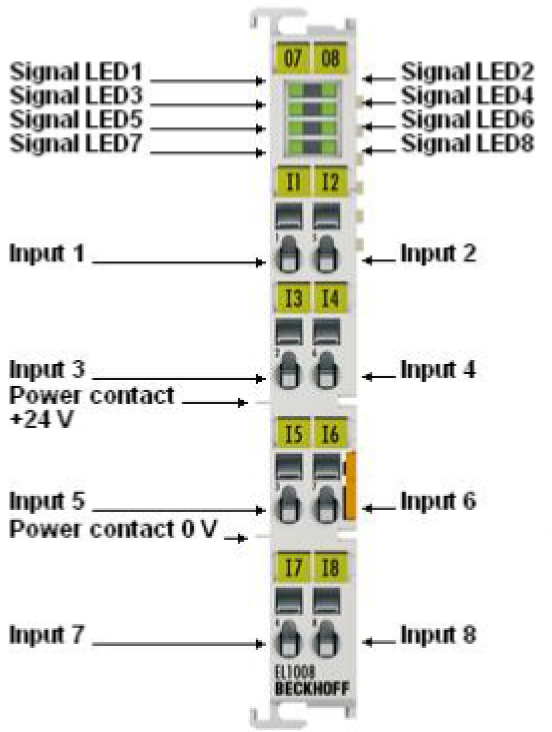


Figure 3.2: Digital Input module EL1008.

EL1008 — 8-channel digital input terminal 24 V DC, 3 ms

The EL1008 digital input terminal acquires the binary control signals from the process level and transmits them, in an electrically isolated form, to the higher-level automation unit. Digital input terminals from the EL100x series have a 3 ms input filter. The EtherCAT Terminals indicate their state via an LED.

3.2.2 Digital output module (EL2008)

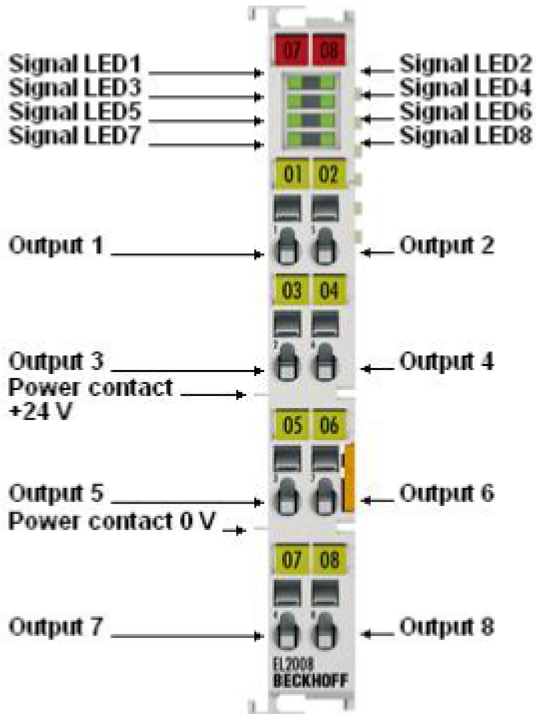


Figure 3.3: Digital Output module (EL2008)

EL2008 — 8-channel digital output terminal 24 V DC, 0.5 A

The EL2008 digital output terminal connects the binary control signals from the automation unit on to the actuators at the process level with electrical isolation. The EtherCAT Terminal indicates its signal state via an LED.

3.2.3 Analog input module (EL3062)

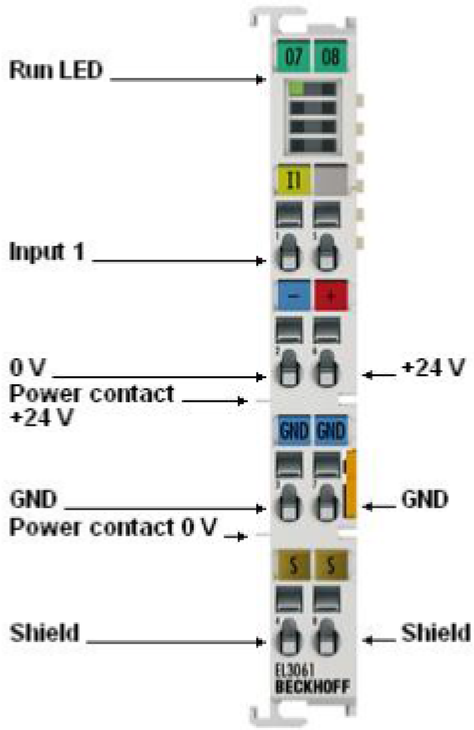


Figure 3.4: Analog Input module (EL3062)

EL3062 — 2-channel analog input terminals 010 V, single-ended, 12 bits

The EL3062 analog input terminals process signals in the range between 0 and 10 V. The voltage is digitized to a resolution of 12 bits and is transmitted, electrically isolated, to the higher-level automation device. The input channels of an EtherCAT Terminal have the reference ground as common ground potential. The EL3062 combines two channels in one housing. The signal state of the EtherCAT Terminals is indicated by light emitting diodes.

3.2.4 Analog output module (EL4002)

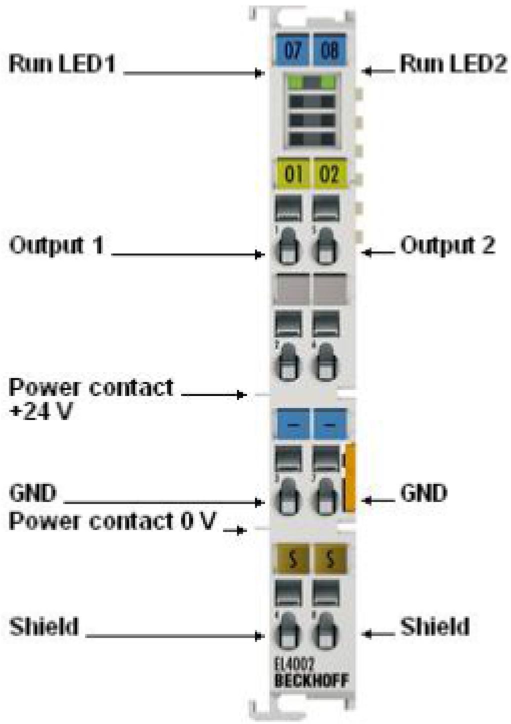


Figure 3.5: Analog Output module (EL4002)

EL4002 — 2-channel analog output terminal 010 V, 12 bits

The EL4002 analog output terminal generates signals in the range between 0 and 10 V. The voltage is supplied to the process level with a resolution of 12 bits and is electrically isolated. The output channels of the EtherCAT Terminal have a common ground potential. The EL4002 combines two channels in one housing. The output stages are powered by the 24 V supply. The signal state of the EtherCAT Terminal is indicated by light emitting diodes.

3.3 RTD Signal Conditioning Circuit XTR105

The circuit is designed to work in temperature range of 0-100 C. Corresponding 1-5 VDC is generated to the variation in RTD's resistance i.e. at 0C output is 1 VDC and at 100C output is 5 VDC.

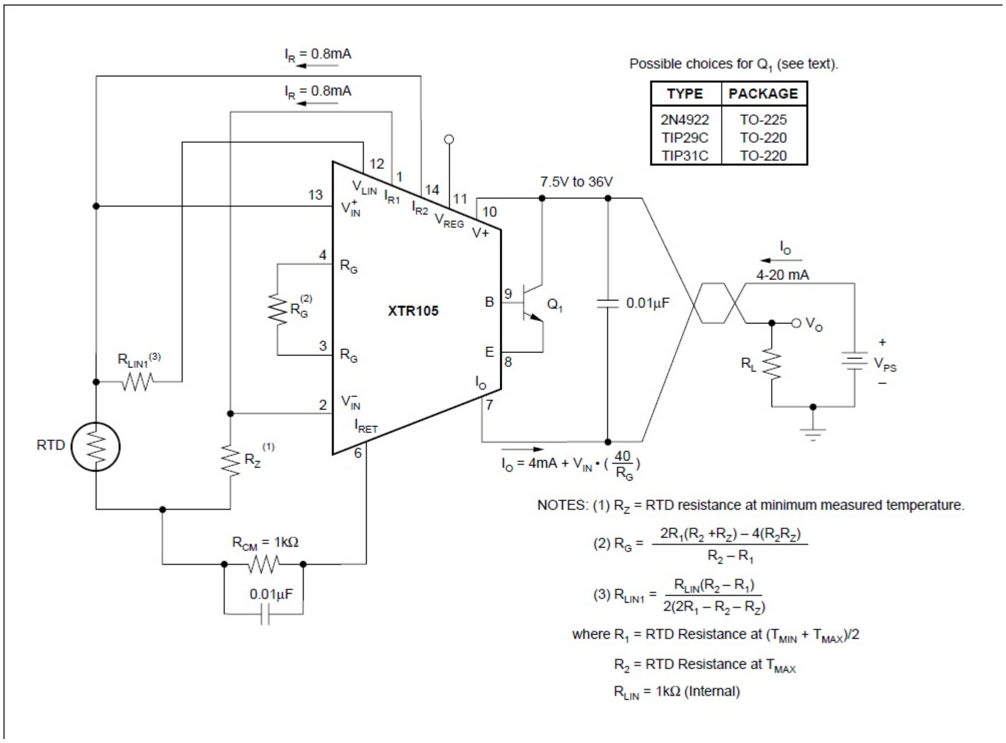


Figure 3.6: XTR-105 Circuit Diagram

3.4 AC Heater Control Circuit

To control the AC heater it is necessary to generate equivalent PWM signal corresponding to the Output required. Input control signal is 0-10 VDC i.e when its 0 VDC there is 0% duty cycle and when input is 10 VDC it generates 100% duty cycle.

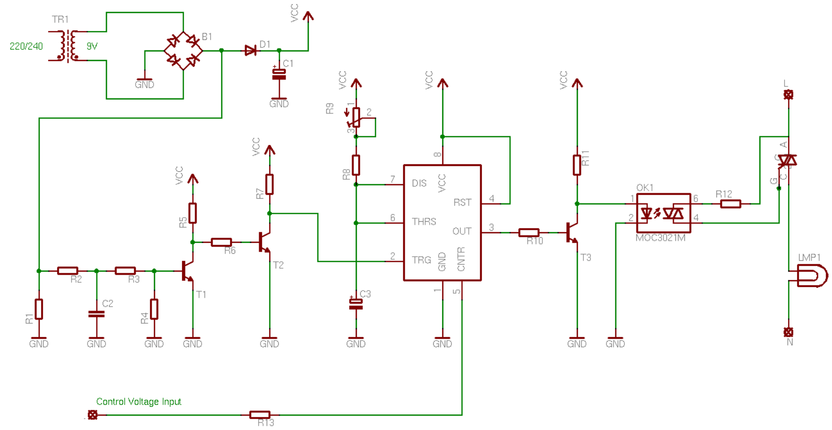


Figure 3.7: Heater Control Circuit

3.5 Physical System

A temperature system was developed such that it exhibits the effect of variable time delay. For that a galvanized tank of size 15X8X10.5 (lxbxh) was divided into equal half by placing a metal sheet in the center. In one half, a heater of 1.5KW was inserted into the tank to heat the water to desired setpoint. Along with heater a stirrer operated with 12VDC motor was placed for uniform distribution of heat in water. An exhaust fan was used so that when the temperature had to be brought down, fast dissipation of heat in environment was possible which reduces the sluggishness in system.

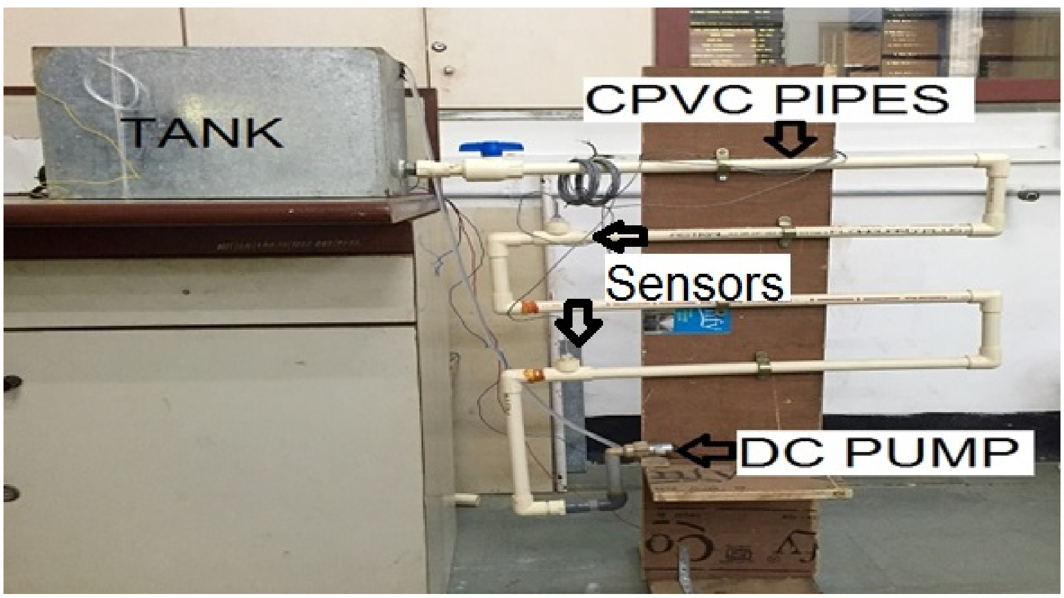


Figure 3.8: Physical Model

When the temperature of this tank is to be controlled it can be considered as first order system since it is independent of second tank behavior. When the temperature of the second tank is to be controlled it can be considered as second order system, since changes in the first tank affects the second tank i.e. heat transfer takes place from first tank to second tank. There is an outlet in second tank and the water is circulated back in the second tank by 12VDC pump through CPVC pipes. When the temperature of second tank is controlled by placing the sensor 3 ft. away from tank there is a small time delay introduced in the system and it can be considered as second order with small dead time, similarly when the temperature of second tank is controlled by placing the sensor 6 ft. away from the tank it can be considered as second order with large dead time.

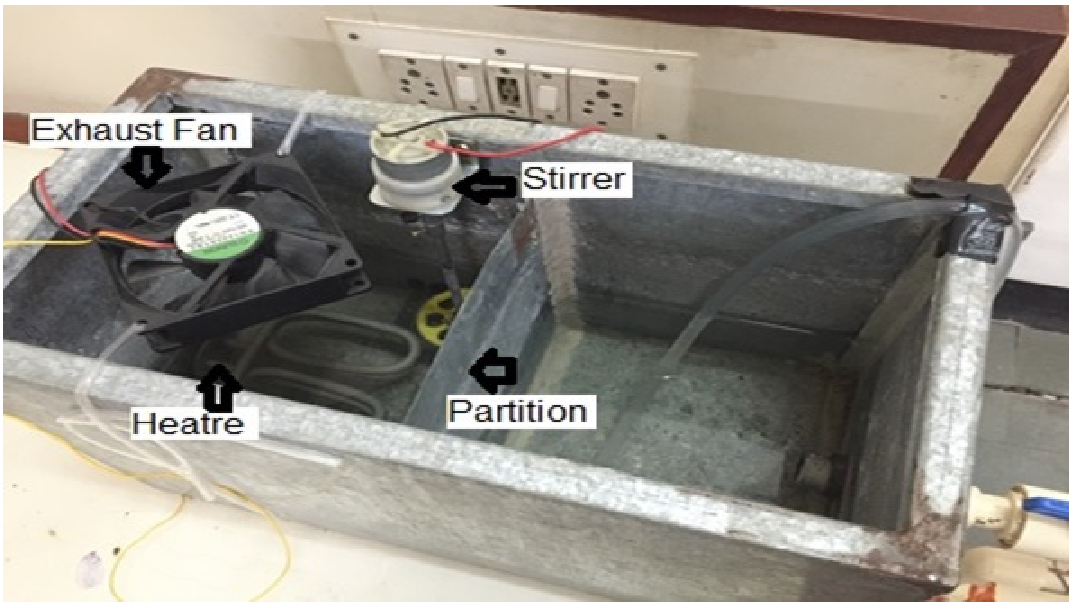


Figure 3.9: Physical Model

Sensor used to measure the temperature was RTD Pt-100. A signal conditioning circuit was designed to give output in the range of 1-5V. The output of signal conditioning circuit was then given to PLCs analog input (EL-3162) and the temperature was displayed on TwinCAT software by scaling input 1-5V to corresponding 0-100 C. TwinCAT software was integrated with 3rd party software like NI LabVIEW 2013 and all the control algorithms were developed on NI LabVIEW platform. Controller output from LabVIEW was then given to PLCs Analog Output (EL-4002) via TwinCAT software. Output from the analog module was then given to heater control circuit. Depending upon output from analog module i.e 0-5V equivalent PWM is generated and heater is operated accordingly i.e. at 0V heater is completely ON (100% duty cycle) and at 5V heater turns OFF (0% duty cycle).

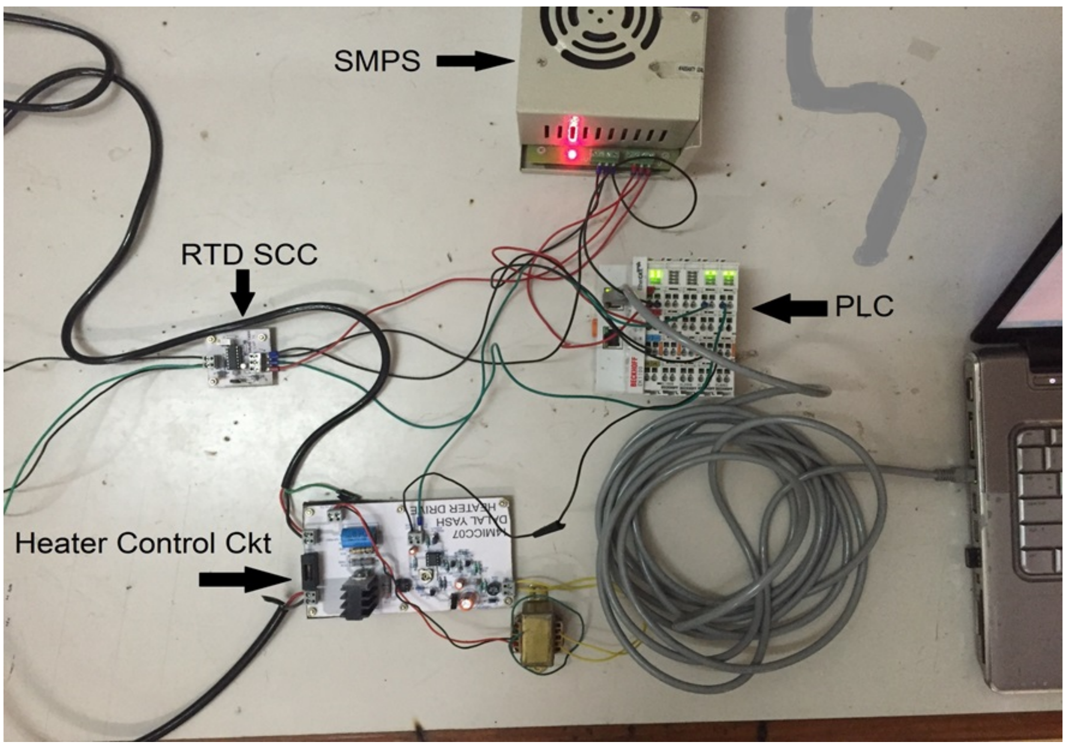


Figure 3.10: Electrical Circuits

Chapter 4

Software

4.1 TwinCAT

TwinCAT PLC offers all the 6 languages (IL, FBD, LD, SFC, ST and CFC) in the IEC 61131-3 standard and has a powerful development environment for programs whose code size and data regions far exceed the capacities of conventional PLC systems.

4.1.1 Programming Languages

- Ladder diagram (LD), graphical.
- Function block diagram (FBD), graphical.
- Structured text (ST), textual.
- Instruction list (IL), textual.
- Sequential function chart (SFC), graphical.
- Continuous Function Chart (CFC), graphical..

4.2 NI-LabVIEW

LabVIEW is an acronym for Laboratory Virtual instrumentation engineering workbench and programming style used is graphical programming. LabVIEW is very user friendly as compared to other text based programming languages because in LabVIEW programmer simply needs to arrange and wire relevant icons together. LabVIEW programs are called virtual instrumentation (VI) as it replicates real world instruments like CRO, multimeter etc. in software. LabVIEW has three main elements: Font panel, block diagram and connector panel. In front panel user places the relevant controls and indicators. In block diagram user builds the code by placing In connector panel user is allowed to represent single VI as a sub VI icon which can be called in other VI. Control design and simulation toolbox is of a great help in process control applications. It has wide range of controllers from simple PIDs and auto tune PIDs to advanced controllers like MPC and fuzzy logic. Once can implement a controller of his choice with the help of this toolbox for eg. Smith Predictor, gain scheduling etc. Real time Data logging is also possible in LabVIEW, user can select one of these file formats xlsx , LVM, TDM ,TDMS. With the help of system identification icon in control design and simulation toolbox and data logging one can find the model of any given system.

4.2.1 Modules used

LabVIEW Control Design and Simulation Module

With the LabVIEW Control Design and Simulation Module, one can simulate dynamic systems, design sophisticated controllers, and deploy your control systems to real-time hardware. One can use both classical and state-space approaches to design controllers and estimators. When you integrate this module with the LabVIEW MathScript RT Module, and can perform textual mathematics and algorithm design in LabVIEW using the .m file syntax.

System Identification Toolkit

- This toolkit is now included in the Advanced Signal Processing Toolkit and the CDS Module.

- Identify dynamic system models directly from real-world stimulus and response signals.
- Seamlessly integrate data acquisition for both time- and frequency-based system identification.
- Integrate with other LabVIEW modules to build adaptive control algorithms.
- Parametric, polynomial, frequency-based, and grey box algorithms.

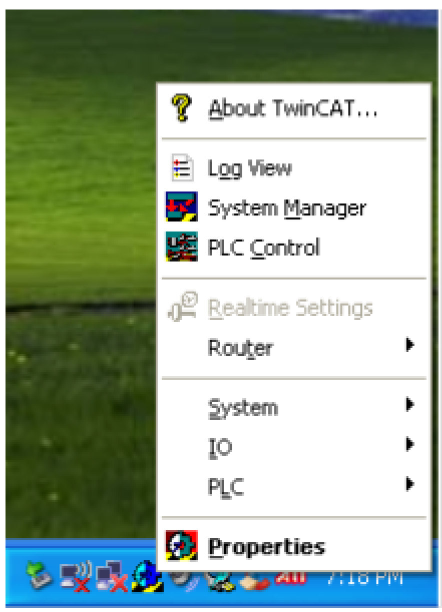
NI LabVIEW PID and Fuzzy Logic Toolkit

- This toolkit is now included in LabVIEW Full and Professional.
- Use the Fuzzy System Designer and Fuzzy Logic VIs to design, adapt, and control fuzzy systems
- Integrate P, PI, PD, and PID control algorithms into your LabVIEW applications
- Autotune gains online and offline based on different algorithms to improve control performance
- Take advantage of advanced features including gain scheduling and integral antiwindup

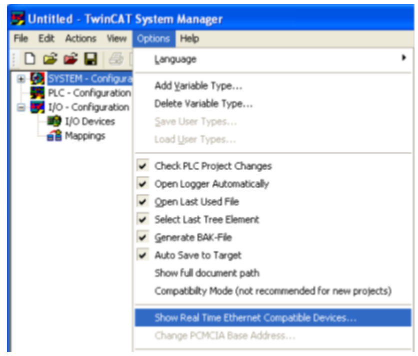
Chapter 5

Interfacing Hardware and Software

- **Step 1 : Installation of TwinCat Ethernet adapter.**
  1. Goto TwinCat system manager.



  2. Click on Show real time Ethernet compatible device from Options.



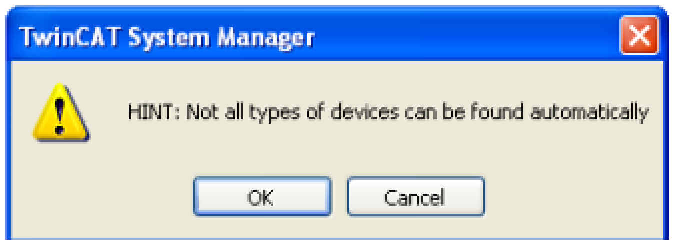
3. If LAN Connection is shown under Compatible or Incompatible Devices then Select LAN Connection and Click on Install.

4. After Installing TwinCAT Ethernet adapter, LAN Connection will be Shown under Installed and Ready to use devices.

- **Step 2 : Scanning of hardware in system manager.**

1. Right click on I/O devices and select Scan Devices.

2. Select OK when it asks for Not all types of devices can be found automatically.



3. Select EtherCAT and Press OK.

4. Click YES when it asks for Scan for boxes.

5. Click NO when it asks for Activate free run.

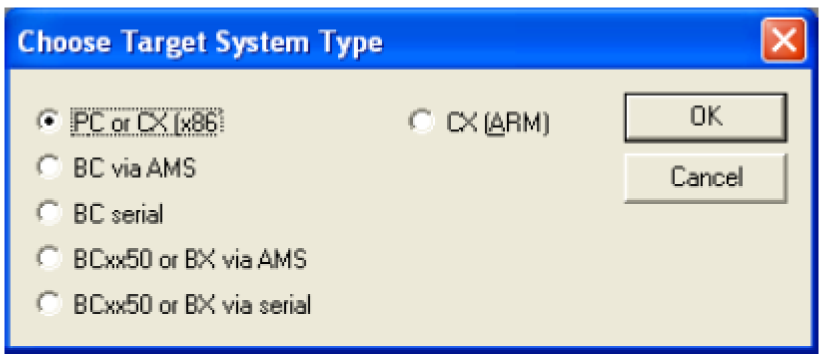
- **Step 3 : Active free run.**

1. Click on Toggle free run state to activate free Run mode.

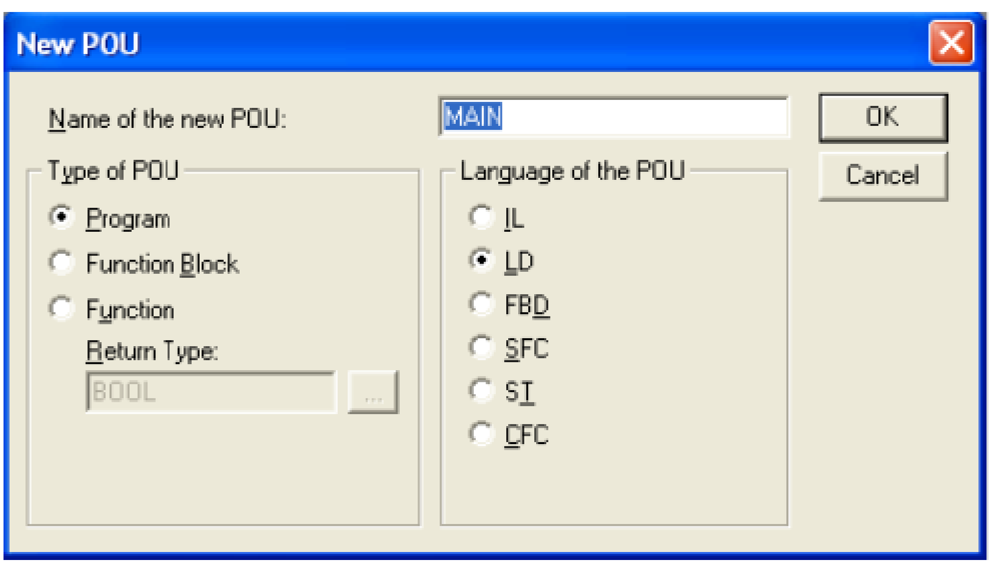
- **Step 4 : Creating a new project in TwinCAT control.**

1. Go-to Files and select New file.

2. Select PC as a target and click OK.



3. Select POU as Program and Language as LD.

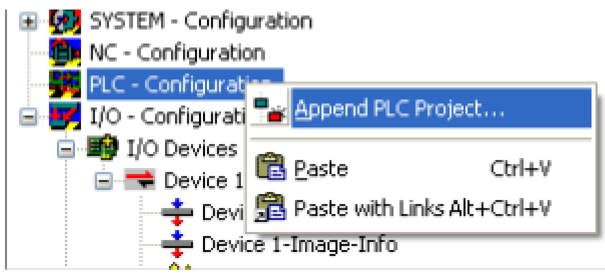


4. Declaration of variables and writing a program.

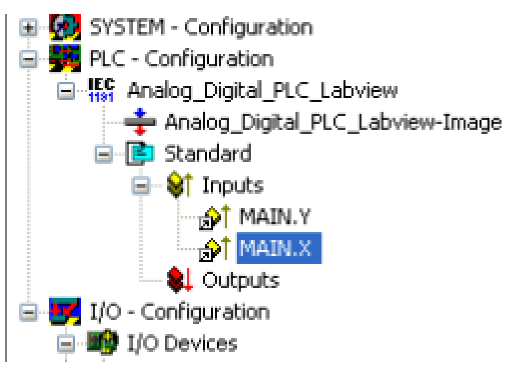
5. Save the project at desired location with *.Pro extension.
6. Go to Project and select Rebuild all to check for errors

- **Step 5 :Appending PLC project in system manager.**

1. Go back to system manager again and right click on PLC Configuration and select Append PLC project



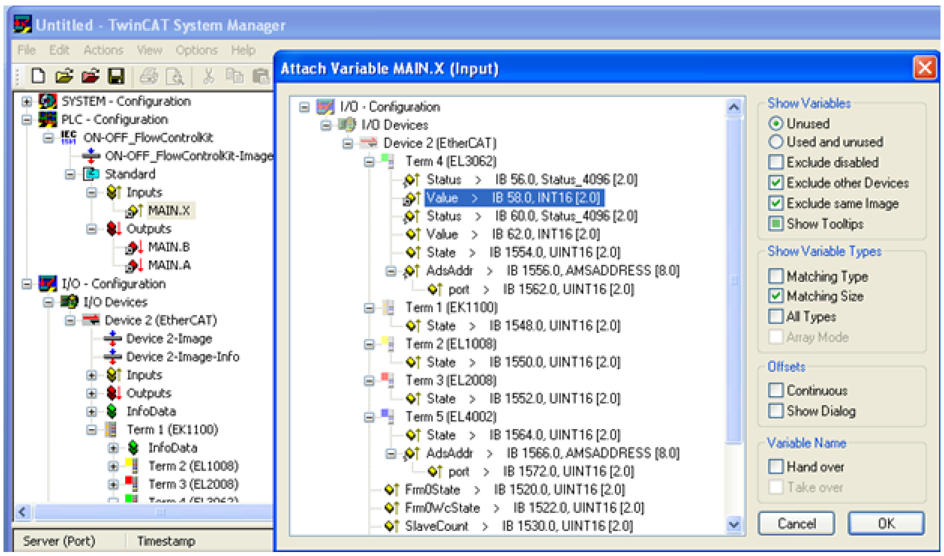
2. Select the project with *.tpy Extension.
3. List of all PLC variables will be appended.



- **Step 6 : Linking of PLC variables with Input / Output.**

  1. Right click on the PLC variable i.e. X in above case and select Change link.

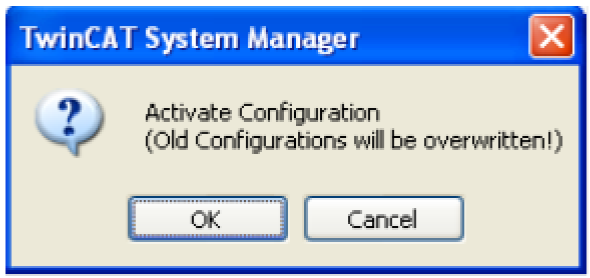
  2. Select corresponding input address from the list and press OK and repeat this for all input and output variables



- **Step 7 : Saving the configuration.**

1. Click on Active Configuration in system manager.

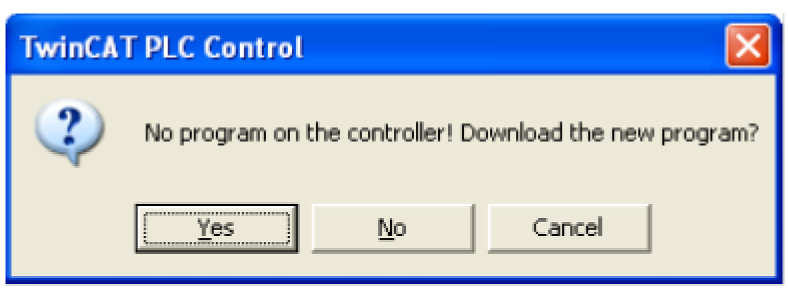
2. Select OK to Activate configuration



3. Select OK to Restart TwinCAT system in Run mode

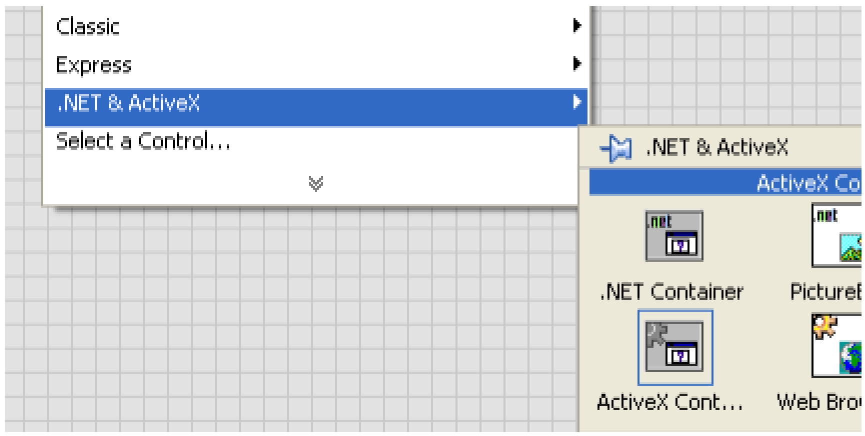
- **Step 8 : Download PLC project.**

1. Go back to TwinCAT PLC controller and click on Login(F11)
2. Click OK to download the new program.
3. Then put the PLC in Run mode(F5).

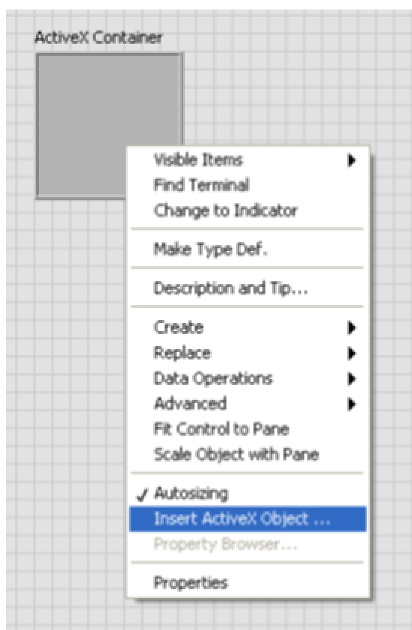


- **Step 9 :Integration of TwinCAT ADS-OCX in LabVIEW.**

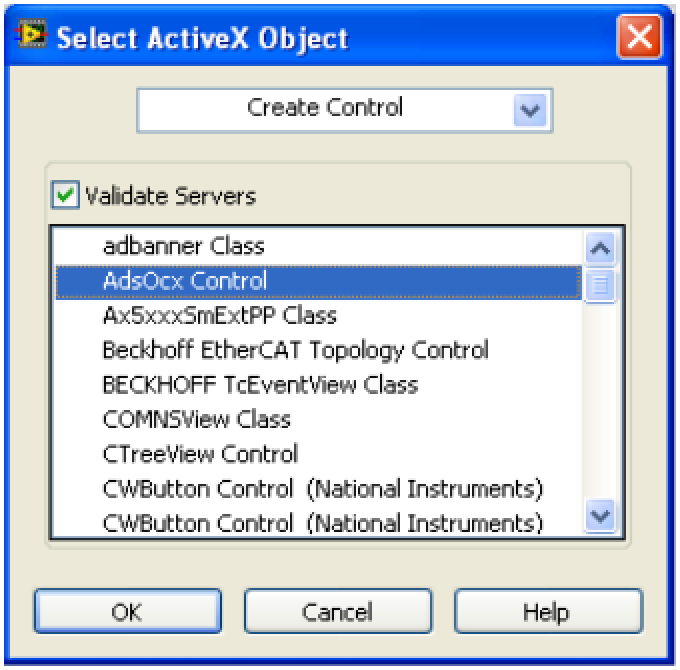
1. Right click on front panel and select ActiveX container.



2. Right click on ActiveX container and select Insert ActiveX Object.



3. Select AdsOcx Control.



4. Insert AdsOcx Element in LabVIEW

Front Panel:

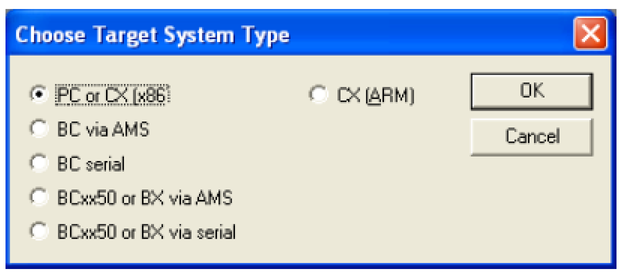
Block Diagram:

5.1 Digital Read, Digital write, Analog read, Analog write.

- **Repeat Steps 1-3.**
- **Step 4 : Creating a new project in TwinCAT control.**

1. Go-to Files and select New file.

2. Select PC as a target and click OK.



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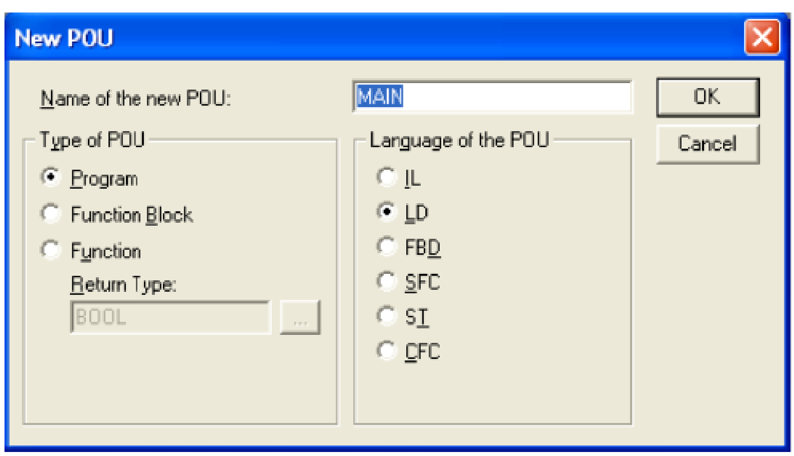
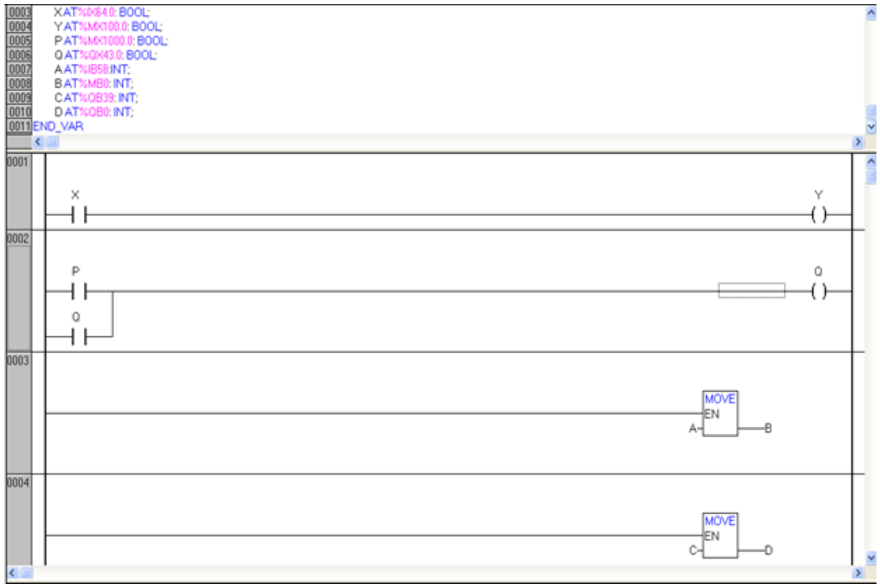


4. Declaration of variables and writing a program.

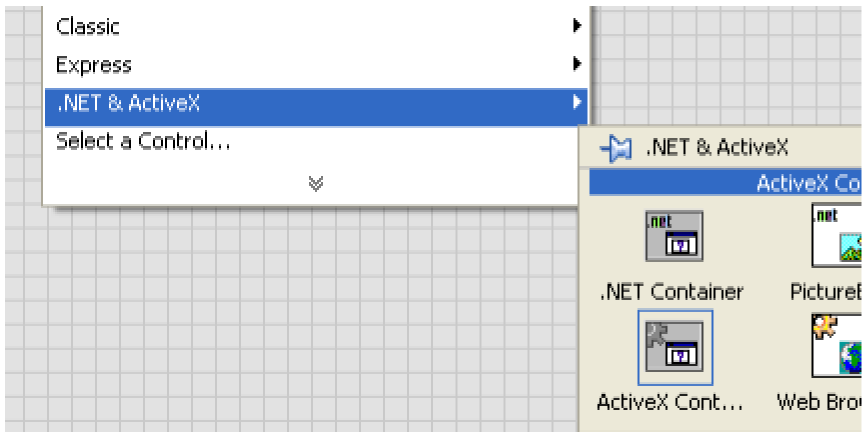


5. Save the project at desired location with *.Pro extension.
6. Go to Project and select Rebuild all to check for errors

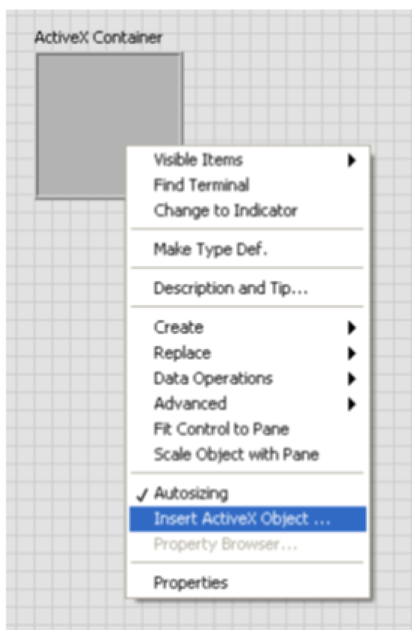
- **Repeat Steps 5-8.**

- **Step 9 :Integration of TwinCAT ADS-OCX in LabVIEW.**

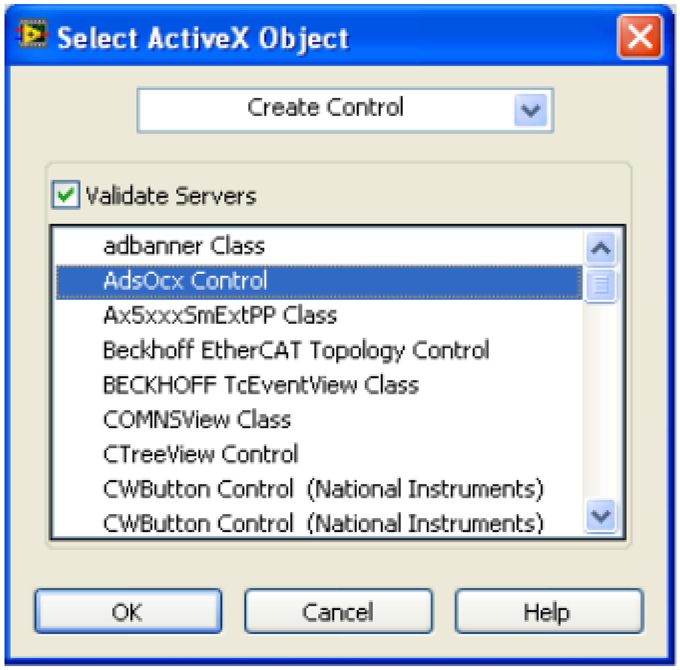
1. Right click on front panel and select ActiveX container.



2. Right click on ActiveX container and select Insert ActiveX Object.



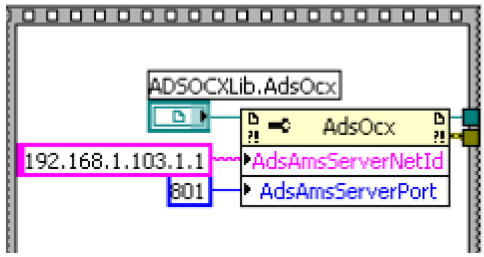
3. Select AdsOcx Control.



4. Insert AdsOcx Element in LabVIEW

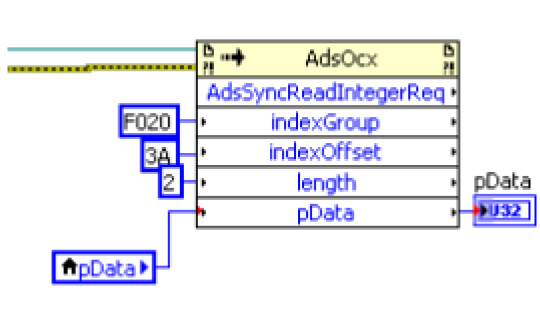
Front Panel:

Block Diagram:

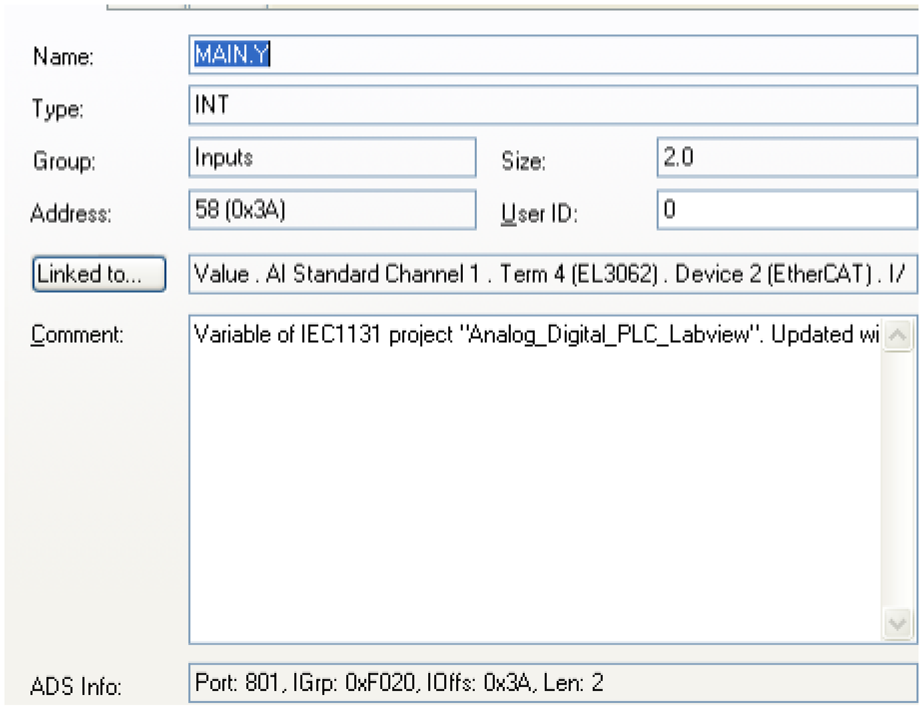


In AdsAmsServerNetId write the Id given in the bottom of TwinCAT system manager.

5. We need to read digital data, write digital data, read analog data and write analog data we need to select corresponding Methods for ADSOCXLib.Adsocx class i.e.to read analog data select AdsSyncRead-IntegerReq.



6. Values of index group , index offset, length for respective input or output can be found from system manager.



7. After assigning all the inputs and outputs put the LabVIEW in RUN mode.

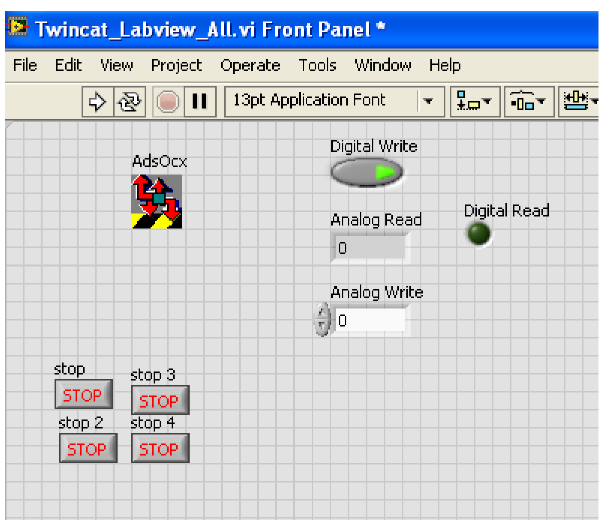


Fig 5.1 Interfacing Front Panel

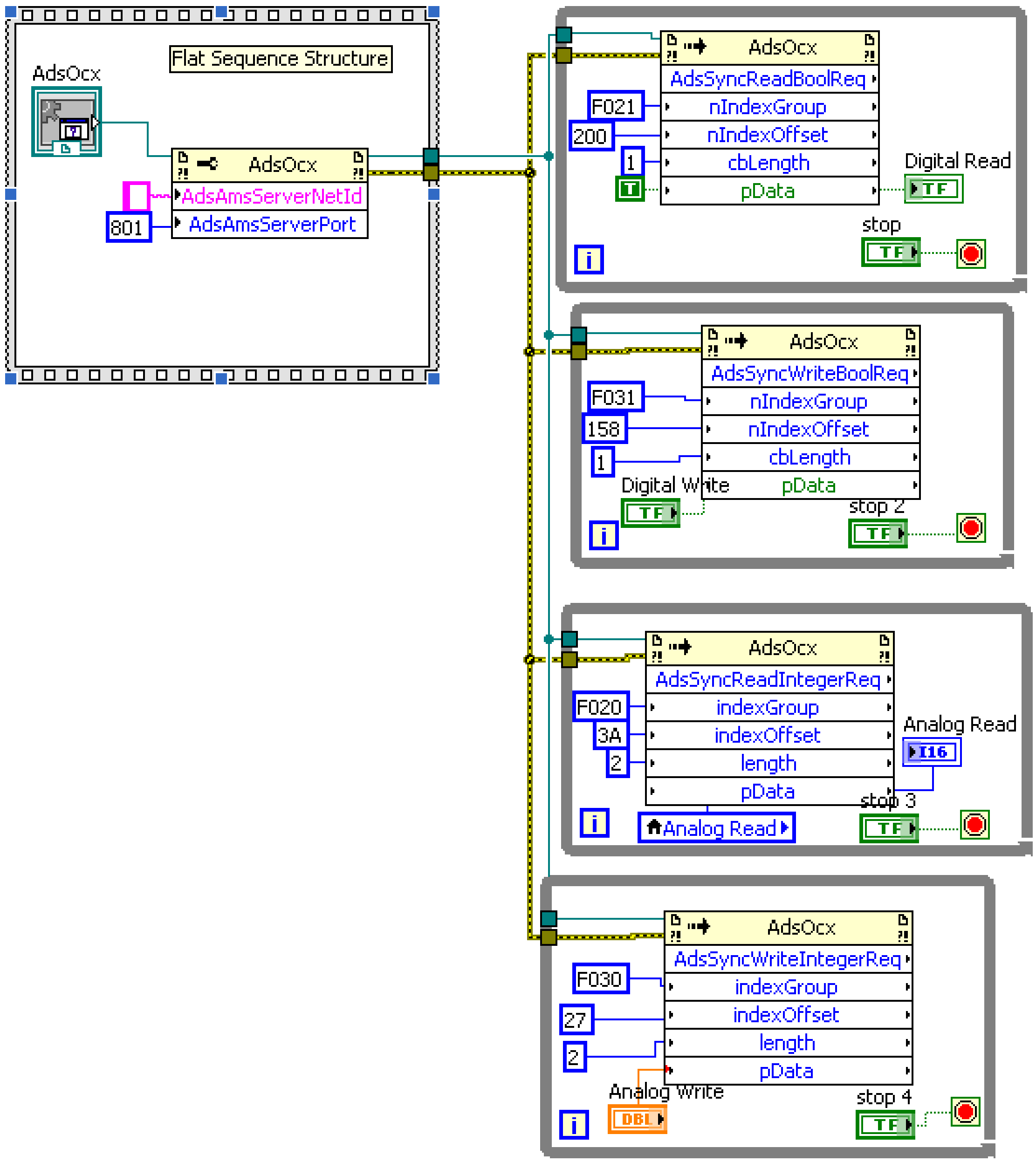


Fig 5.2 Interfacing Block Diagram

5.2 TwinCat PLC in LabVIEW

This exercise deals with creating the whole PLC structure in NI-LabVIEW and all the controls are done from NI-LabVIEW.

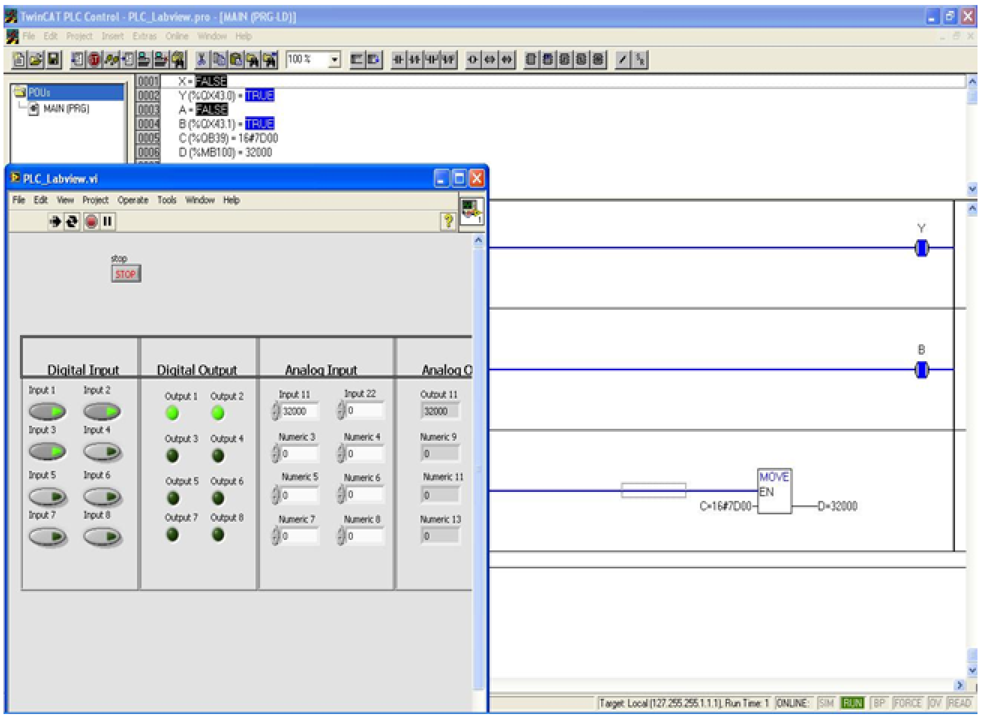


Figure 5.1: TwinCat PLC in LabVIEW

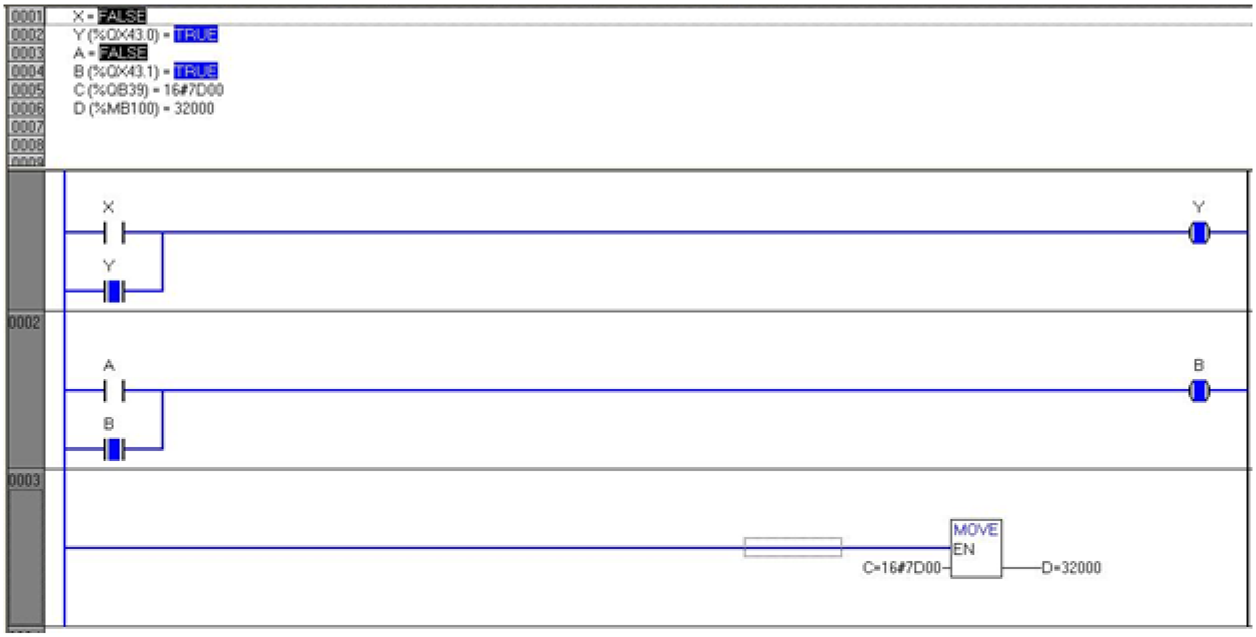


Figure 5.2: Program to Write data from LabVIEW into PLC

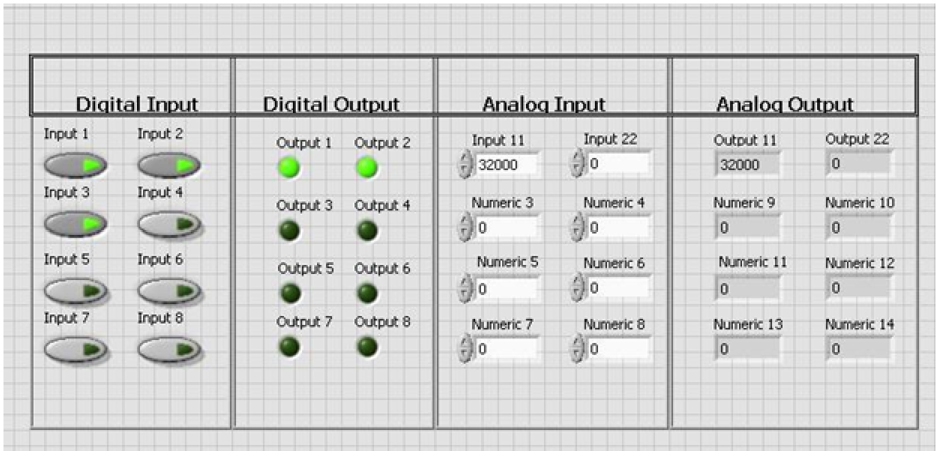


Figure 5.3: LabVIEW Front panel

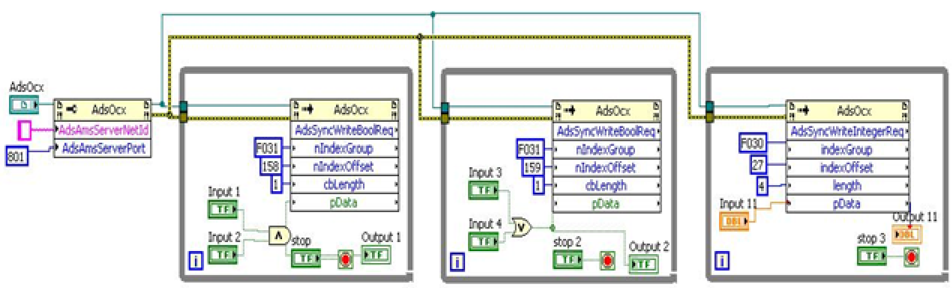


Figure 5.4: LabVIEW Block Diagram

5.3 Simple ON-OFF control of heater

This exercise deals with turning on the heater when the process variable i.e. Temperature is less then setpoint and turning off the heater when the temperature is above the set point.

Case-1: In this case the process variable is 49 which is less then setpoint so the heater is completely ON.

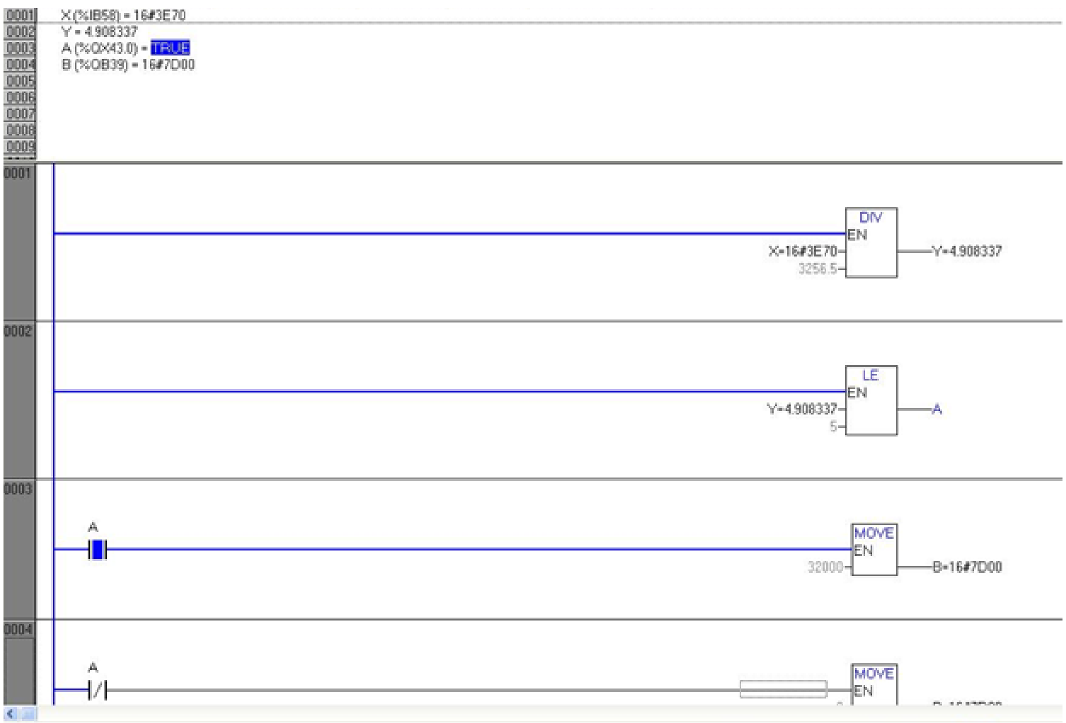


Figure 5.5: Heater ON

Case-2: In this case the process variable is 51 which is greater then setpoint so the heater is completely OFF.

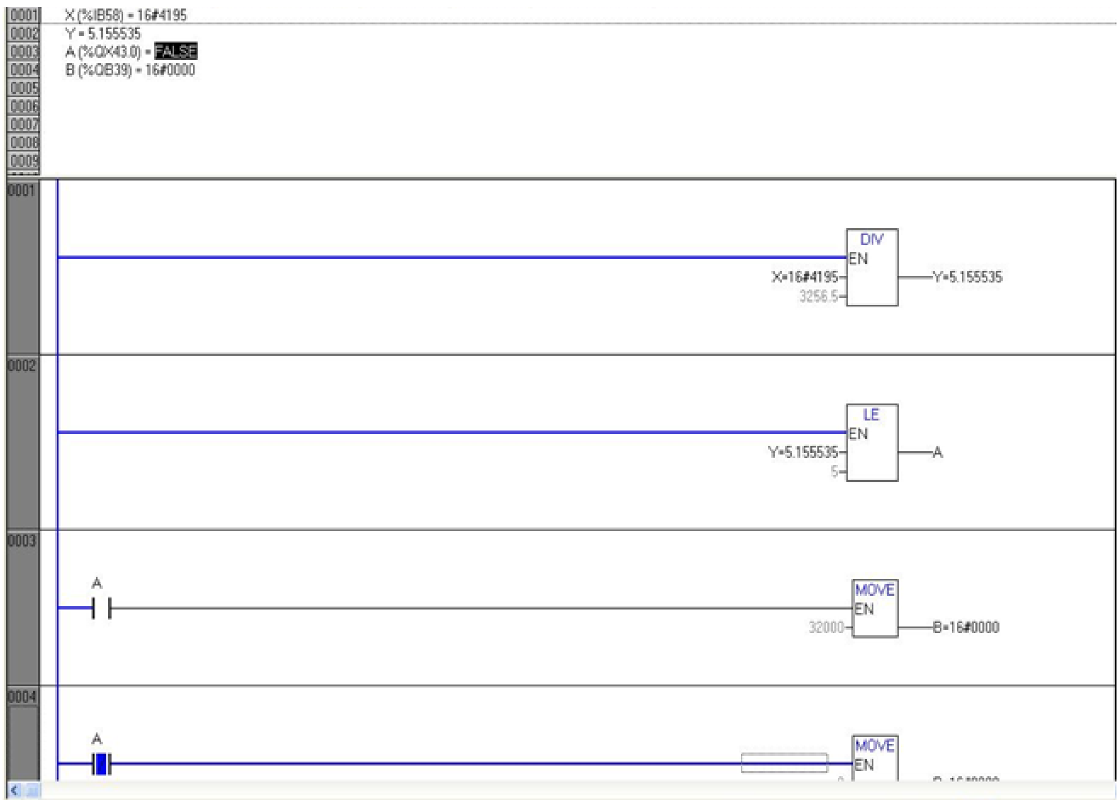


Figure 5.6: Heater OFF

5.4 ON-OFF control of heater with Dead Band

This exercise deal with turning on the heater when the process variable i.e. Temperature is less than 45 and turning off the heater when the temperature is above 55. The range in between 45-55 is known as dead band in which the output remains 0 i.e. no operation takes place at this temperature range.

Case-1 In this case the process variable is 41 which is less then 45 so the heater is completely ON

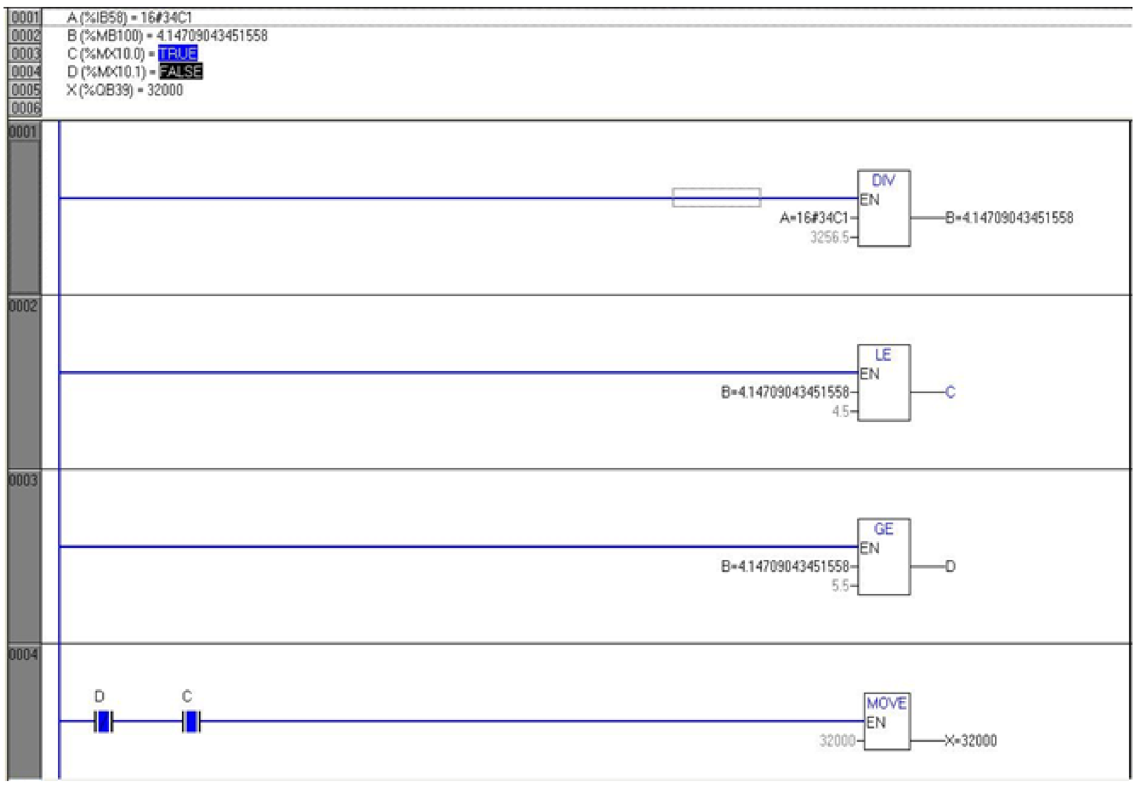


Figure 5.7: Heater ON

Case-2 In this case the process variable is 50 which fall in dead band region so the heater is completely off.

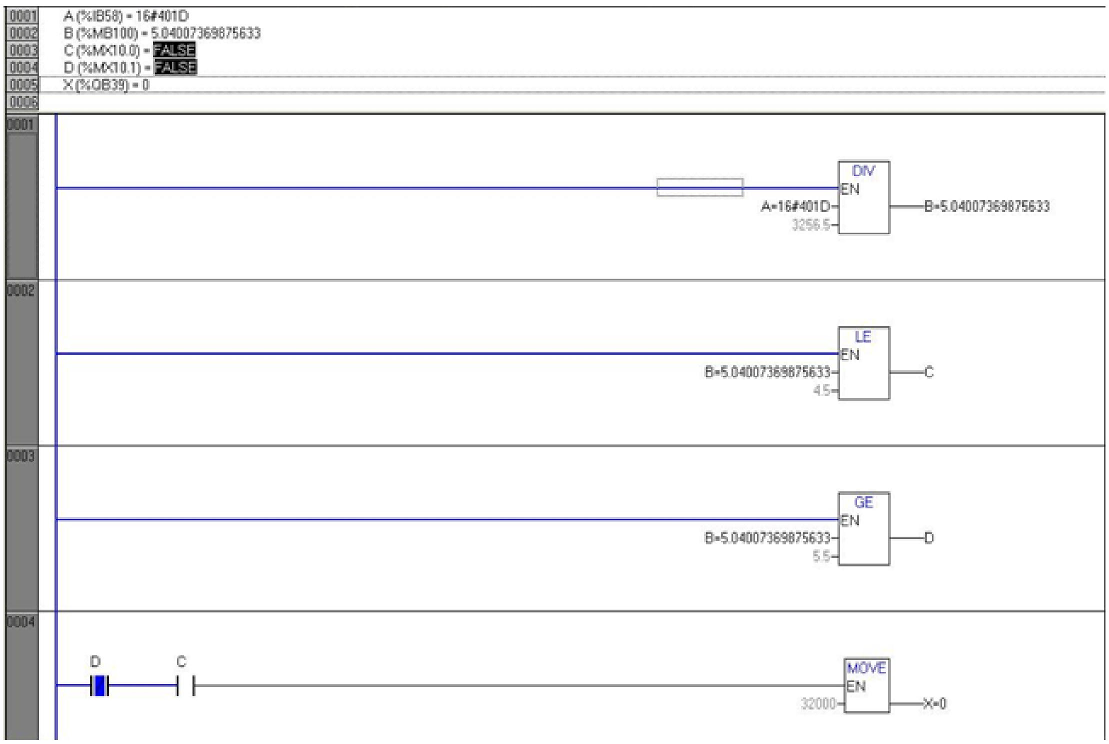


Figure 5.8: Heater OFF due to Deadband

Case-3 In this case the process variable is 60 which is greater then 55 so the heater is fully OFF.

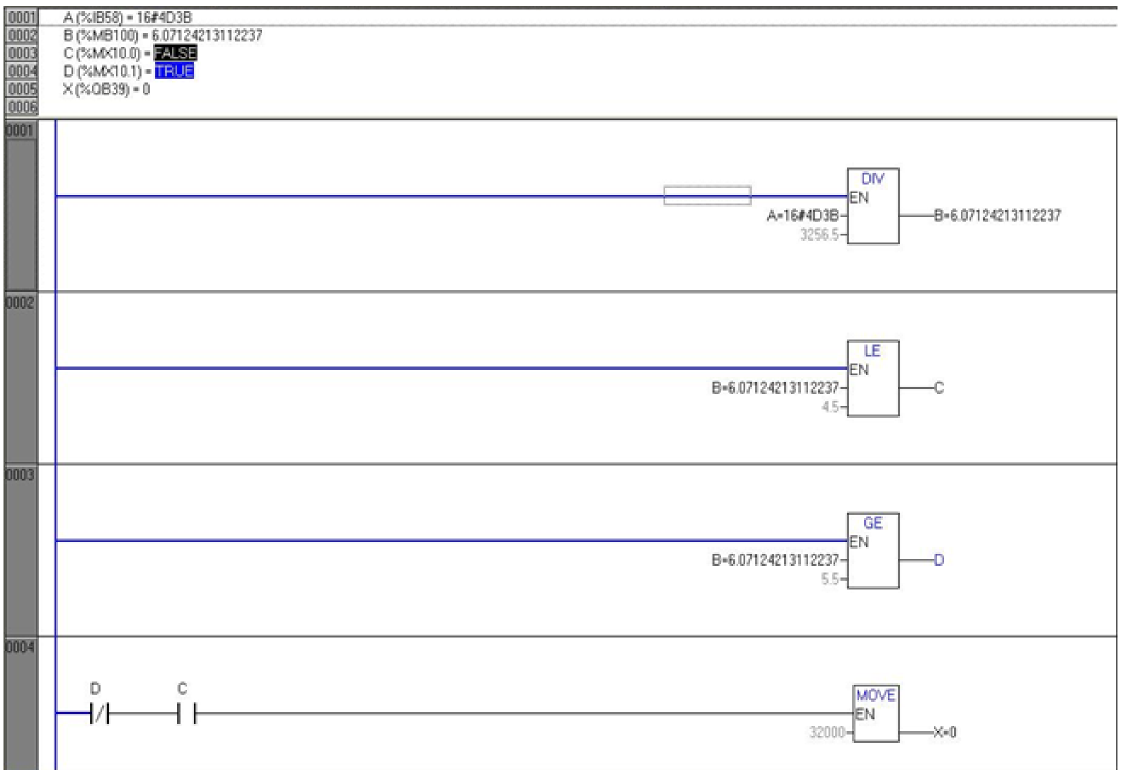


Figure 5.9: Heater OFF

Chapter 6

Integration of physical model with PLC

6.1 Implementation of PID in LabVIEW

Conventional PID controller is developed in LabVIEW using the PID block available in control design and simulation toolbox.

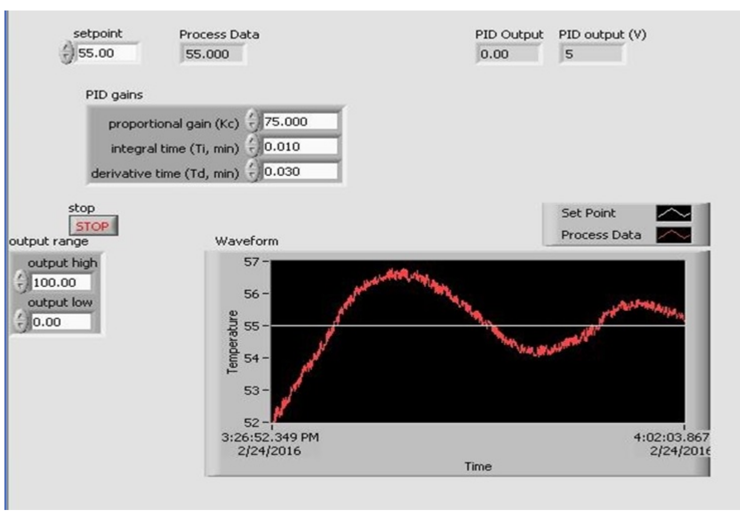


Figure 6.1: PID Front Panel

Data is acquired from PLC and after scaling in LabVIEW is given to PID block, the controller output is scaled to 0-5 V and given to analog output of PLC.

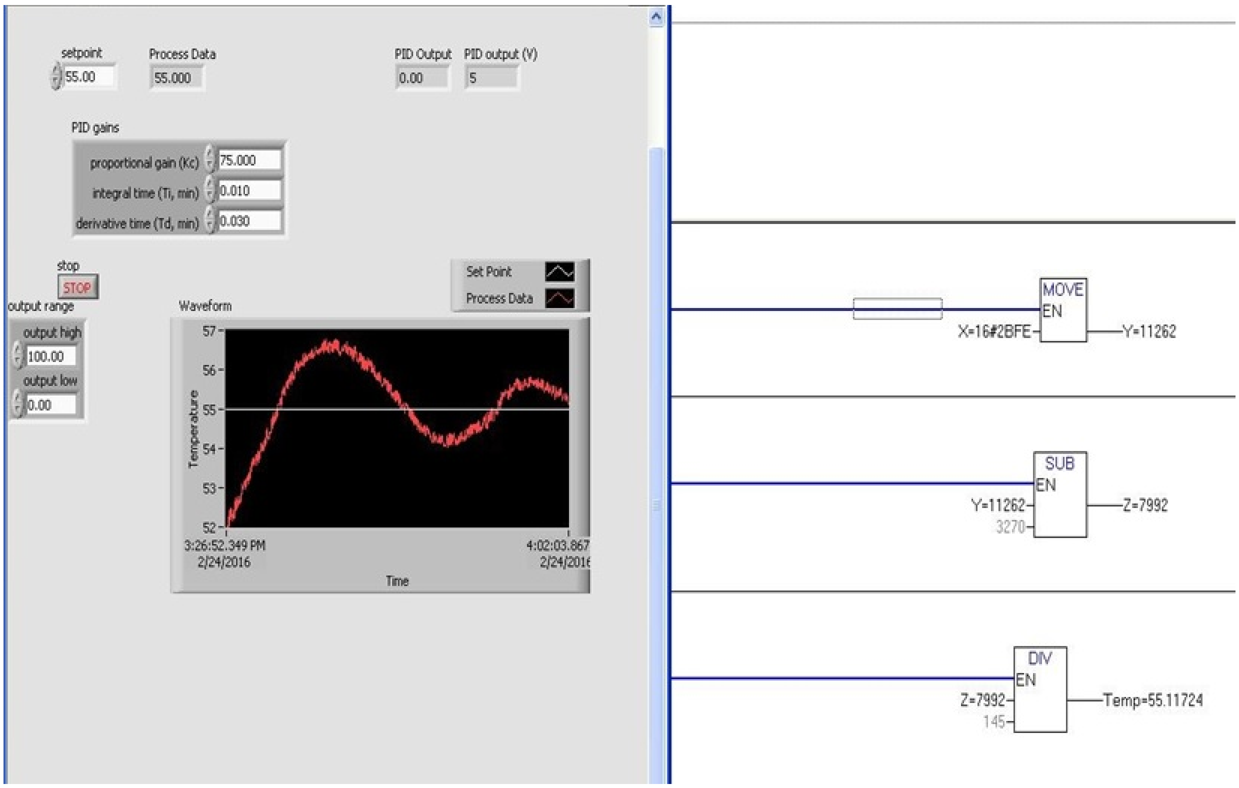


Figure 6.2: TwinCAT and LabVIEW interfacing

6.2 Behavior of PID on Various Process Models.

6.2.1 First Order System

The plot below shows the response of first order system with PID settings as Kp=75 Ti=0.01 Min Td=0.03 Min and Kp=25 Ti=0.01 Min Td=0.03 Min and setpoint was kept 45C. Analysis about Rise time Tr, Peak time Tp,

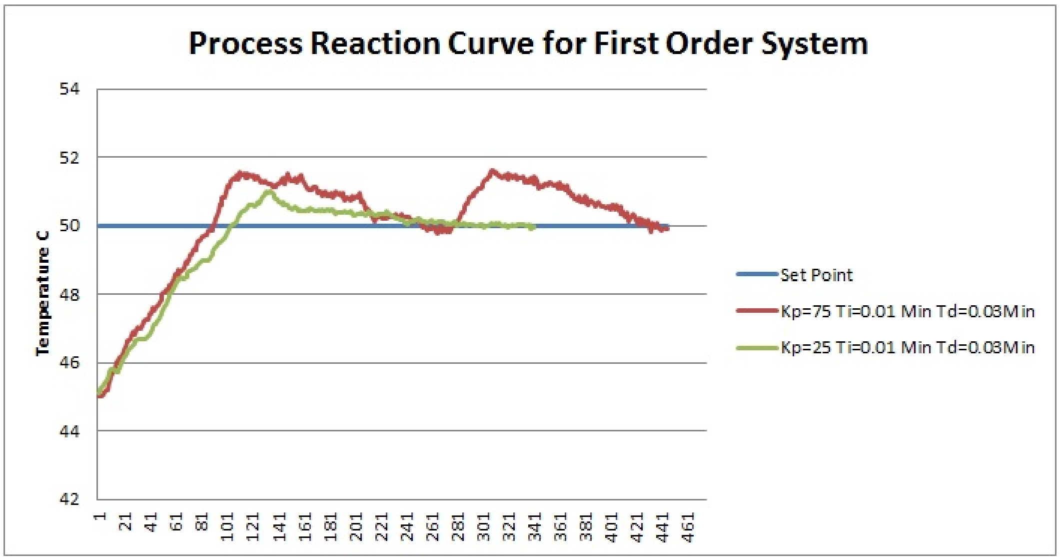


Figure 6.3: Comparison First Order Response

From the above process reaction curve it was observed that the Rise time Tr= 91 Seconds, Peak Time Tp= 121 Seconds and the Overshoot Mp 3.1% when Kp= 75 and Rise time Tr= 105 Seconds, Peak Time Tp= 136 Seconds and the Overshoot Mp 1.9% when Kp=25. Thus it can be concluded that with higher Kp value rise time and peak time reduces but with small Kp value system attains stability.

6.2.2 Second Order System

The plot below shows the response of Second order system for different PID settings as Kp=75 Ti=0.01 Min Td=0.03 Min and Kp=25 Ti=0.01 Min Td=0.03 Min, and setpoint was kept 45C. Analysis for both PID setting about Rise time Tr, Peak time Tp, %Peak Overshoot %Mp were made by observing the plot

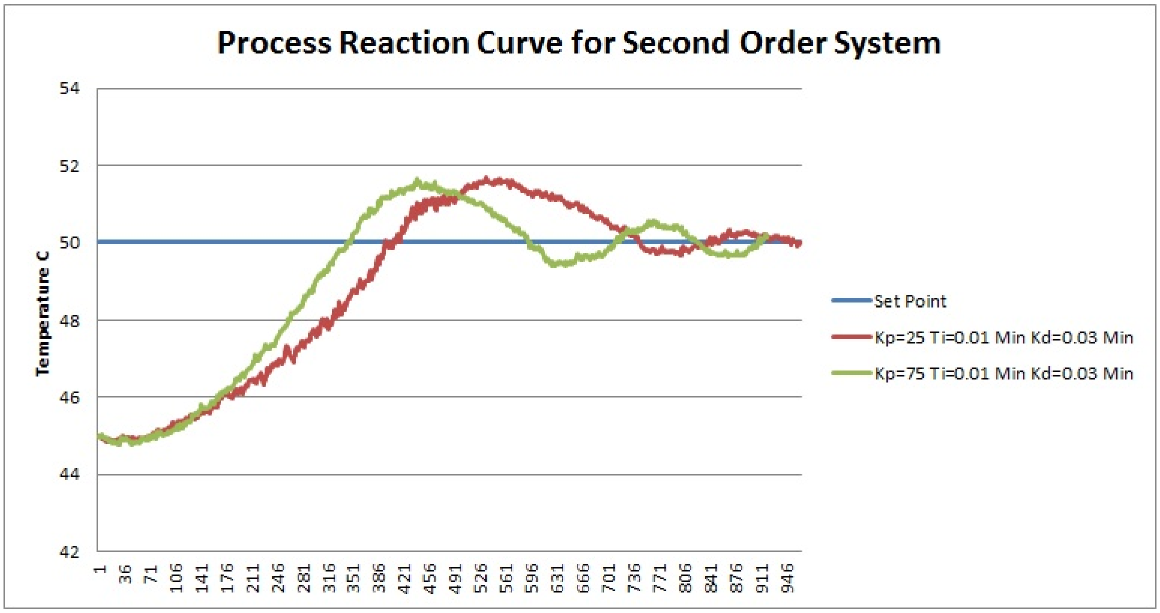


Figure 6.4: Comparison Second Order Response

From the above process reaction curve it was observed that the Rise time Tr=345 Seconds, Peak Time Tp= 441 Seconds and the % Overshoot Mp= 3.2% when Kp=75 and Rise time Tr=394 Seconds, Peak Time Tp= 534 Seconds and the% Overshoot Mp= 3.2% when Kp=25.Thus it can be concluded that by increasing the Gain Kp Rise time Tr and the peak time reduces however there is not much effect on %Overshoot Mp.

6.2.3 Second Order System With Small Time Delay

The plot below shows the responce of Second order system with Small Time delay for different PID settings as Kp=75, Kp=50 and Kp=25 and Ti=0.01Min Td=0.03Min was kept constant, and setpoint was kept 45C. Analysis for both PID setting about Rise time Tr, Peak time Tp, %Peak Overshoot %Mp were made by observing the plot.

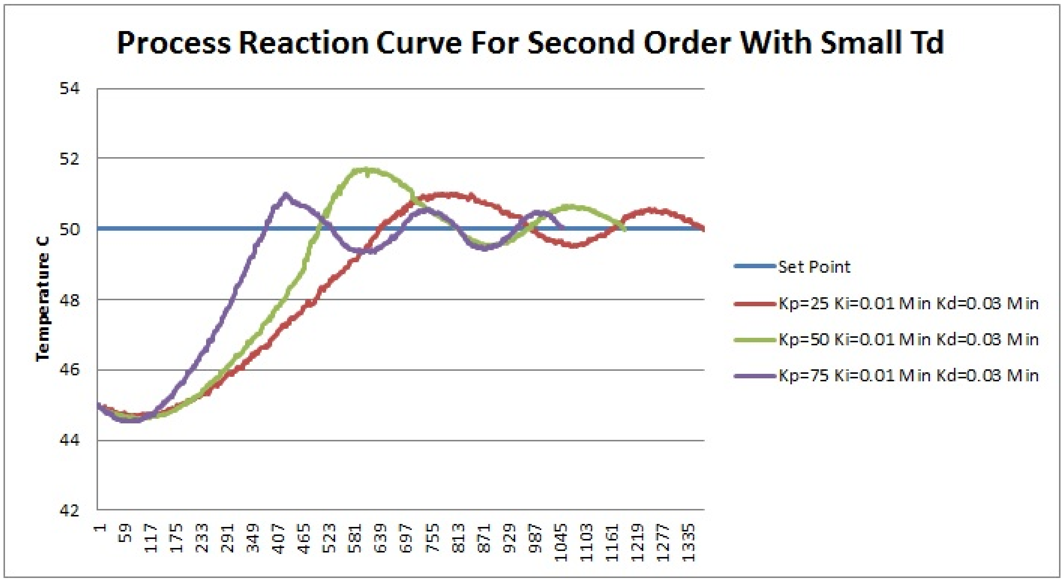


Figure 6.5: Comparison Second Order Small Td

From the above process reaction curve it was observed that the Rise time Tr=382 Seconds, Peak Time Tp= 427 Seconds and the % Overshoot Mp 1.9% when Kp=75, Rise time Tr=502 Seconds, Peak Time Tp= 600 Seconds and the% Overshoot Mp 3.3% when Kp=50 and Rise time Tr=642 Seconds, Peak Time Tp= 781 Seconds and the % Overshoot Mp 1.9% when Kp=25.Thus it can be concluded that by increasing the Gain Kp Rise time Tr and the peak time reduces however there is no effect on %Overshoot %Mp.

6.2.4 Second Order System With Large Time Delay

The plot below shows the responce of Second order system with Large Time delay for different PID settings as Kp=75 Ti=0.01Min Td=0.03Min and Kp=25 Ti=0.01Min Td=0.03Min, and setpoint was kept 45C. Analysis for both PID setting about Rise time Tr, Peak time Tp, %Peak Overshoot %Mp were made by observing the plot.

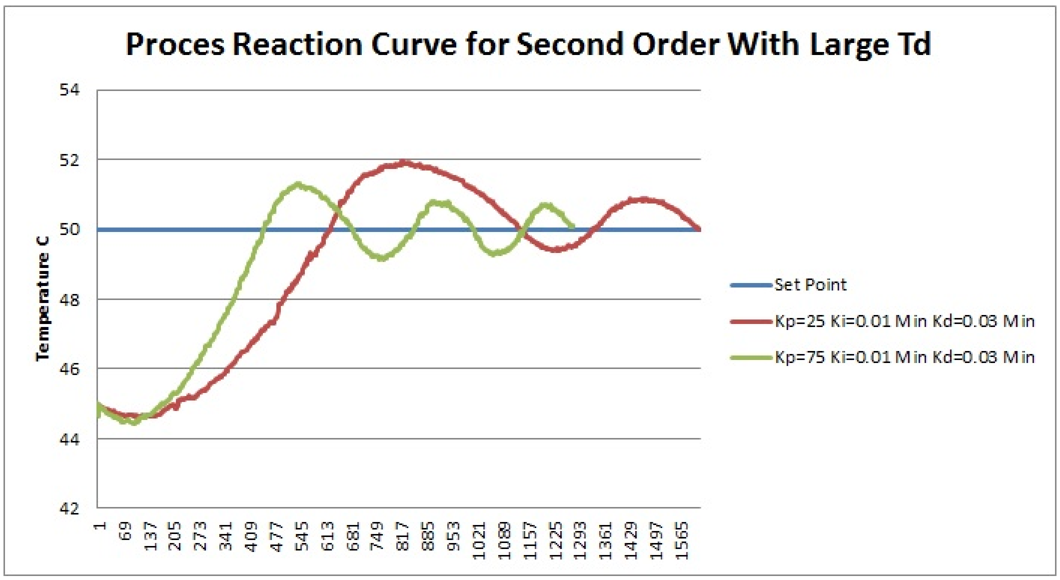


Figure 6.6: Comparison SecondOrder Large Td

From the above process reaction curve it was observed that the Rise time Tr= 449 Seconds, Peak Time Tp= 543 Seconds and the % Overshoot Mp 2.7 % when Kp=75, and Rise time Tr=628 Seconds, Peak Time Tp= 821 Seconds and the % Overshoot Mp 3.9 % when Kp=25.Thus it can be concluded that by increasing the Gain Kp Rise time Tr and the peak time reduces however there is no effect on %Overshoot %Mp.

6.3 Comparative Analysis.

Comparison between all the four models with same PID setting Kp=75 Ti=0.01 Min Td=0.03 Min and constant set point of 50 C was plotted in MATLAB and following analysis were done

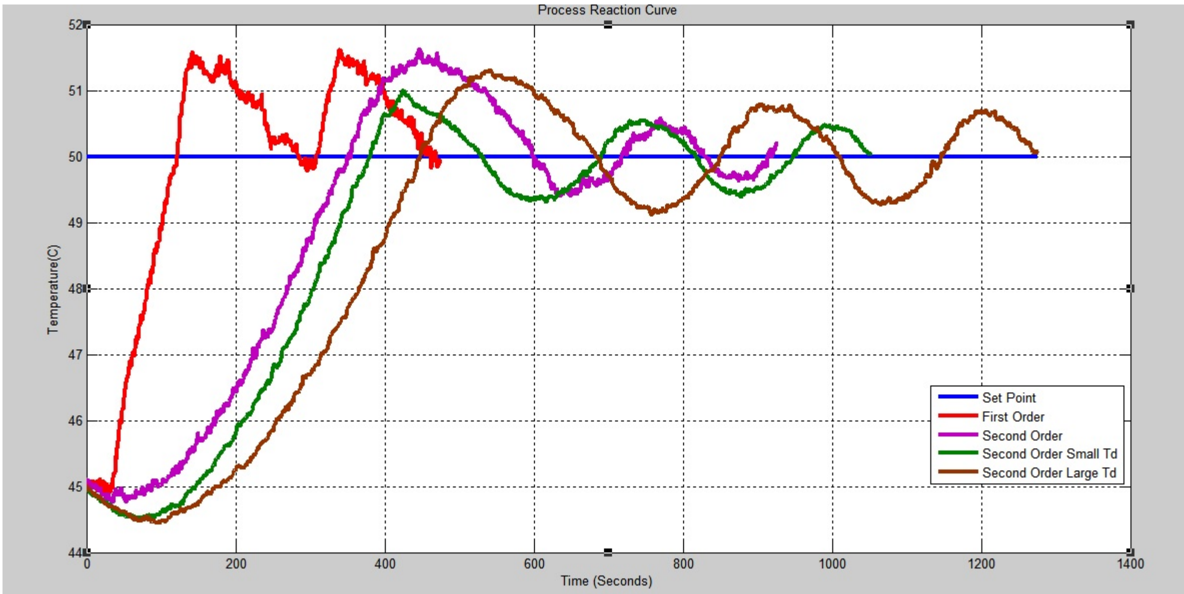


Figure 6.7: Process Reaction Curve

It was observed that as the order of system increases the Rise time Tr and the Peak time Tp increases and with addition of delay in higher order system the rise time and process time further increases. In 1st order system undershoot is very negligible as compared to other three models and with increase in the order of system overshoot remains unaffected.

6.4 Comparison Table for various PID values on different Models.

	First Order System		Second Order System		Second Order System With Small Td		Second Order System With Large Td	
	Kp=75	**Kp=25**	**Kp=75**	**Kp=25**	**Kp=75**	**Kp=25**	**Kp=75**	**Kp=25**
Rise Time Tr	91 Sec	105 Sec	345 Sec	394 Sec	382 Sec	642 Sec	449 Sec	628 Sec
Peak Time Tp	121 Sec	136 Sec	516 Sec	536 Sec	427 Sec	781 Sec	543 Sec	821 Sec
%Peak Overshoot %Mp	3.10%	1.90%	3.20%	3.20%	1.90%	1.90%	2.70%	3.90%

Figure 6.8: Process Reaction Curve

From the above table it was concluded that as the Gain Kp increases the Rise time Tr decreases and Peak time Tp also decreases in all four models thus the sluggishness of higher order system can be reduced but with increase in gain oscillations still persist and thus it can be concluded that PID fails in controlling higher order process with time delay. Thus advanced control algorith like Smith predictor or MPC should be implemented on higher order processes with time delay.

Chapter 7

System Identification

The system was operated in open loop for second order, second order with small Td, second order with large Td for fix amount of time using LabVIEW platform and then the response was plotted in MATLAB and by using ident tool in MATLAB process model was estimated. By using this estimated model Smith predictor was designed.

7.1 Second Order System

Using Ident tool in MATLAB following model was obtained for Second Order System

$$G = \frac{Kp}{(Tp1 * s + 1)(Tp2 * s + 1)(Tp3 * s + 1)}$$

$$G = \frac{7.135}{(10^{-}6 * s + 1)(667.56 * s + 1)(4438.4 * s + 1)}$$

For simplicity in further part higher order systems were converted into First order plus dead time FOPDT using Skogestad method.

$$G = \frac{7.135}{4772.18 * s + 1} e^{-}333.78 * s$$

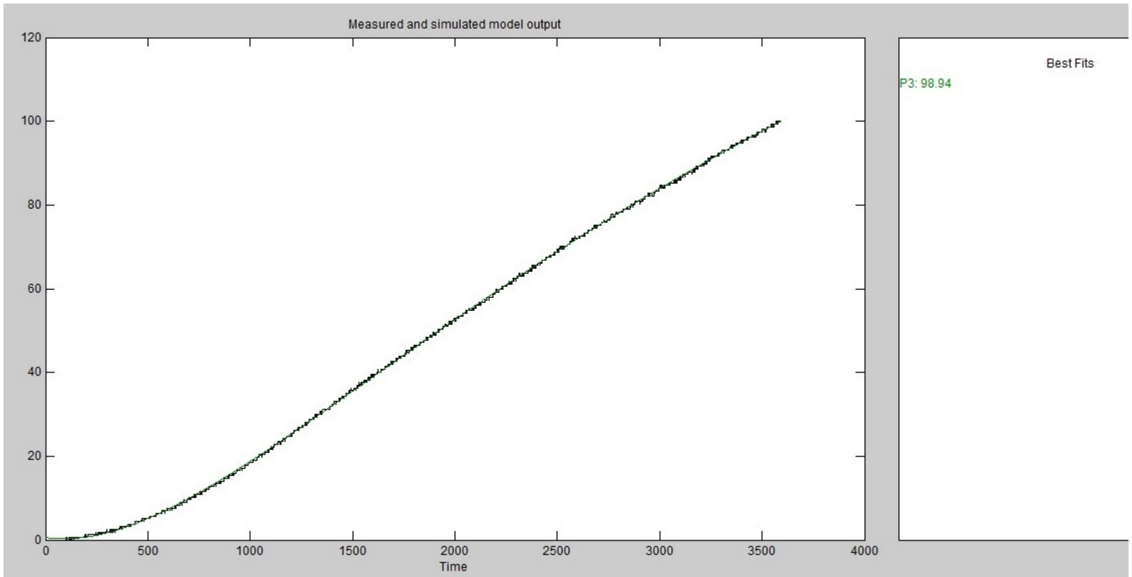


Figure 7.1: Open Loop Response of Second Order

7.2 Second Order System With Small Time Delay

Using Ident tool in MATLAB following model was obtained for Second Order System with Small time delay

$$G = \frac{Kp}{(Tp1 * s + 1)(Tp2 * s + 1)(Tp3 * s + 1)} e^{-}Td * s$$

$$G = \frac{6.457}{(3886.3 * s + 1)(620.35 * s + 1)(188.76 * s + 1)} e^{-}289 * s$$

For simplicity in further part higher order systems were converted into First order plus dead time FOPDT using Skogestad method.

$$G = \frac{6.457}{4196.47 * s + 1} e^{-}498.93 * s$$

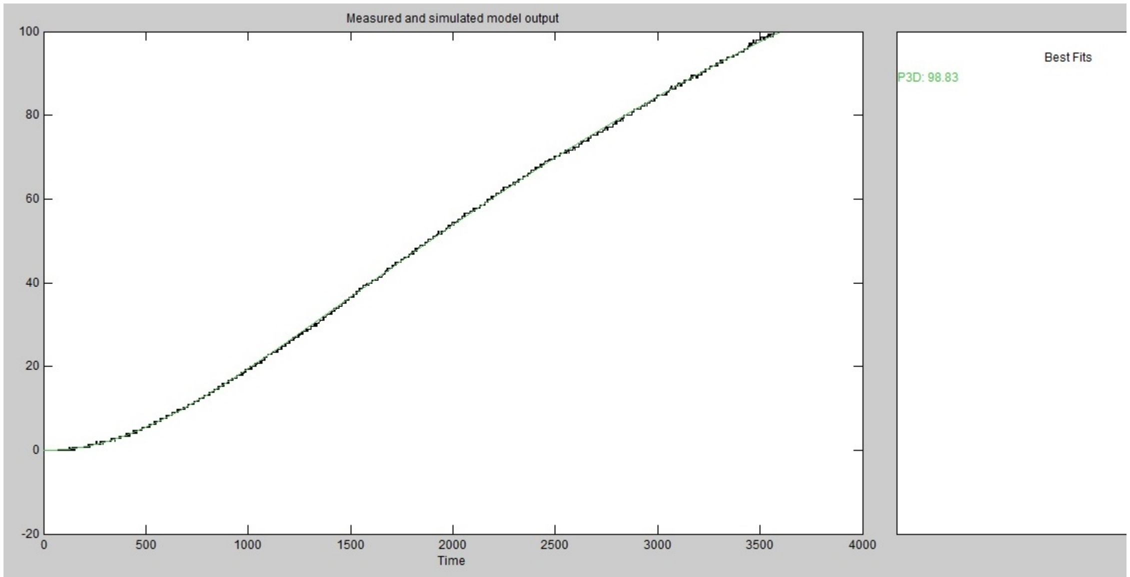


Figure 7.2: Open Loop Response of Second Order With Small Td

7.3 Second Order System With Large Time Delay

Using Ident tool in MATLAB following model was obtained for Second Order System With Large Time Delay

$$G = \frac{Kp}{(Tp1 * s + 1)(Tp2 * s + 1)(Tp3 * s + 1)} e^{-}Td * s$$

$$G = \frac{4.0496}{(10^{-}6 * s + 1)(1246.8.56 * s + 1)(1194 * s + 1)} e^{-}6.13 * s$$

For simplicity in further part higher order systems were converted into First order plus dead time FOPDT using Skogestad method.

$$G = \frac{4.0496}{1843.8 * s + 1} e^{-}603.130 * s$$

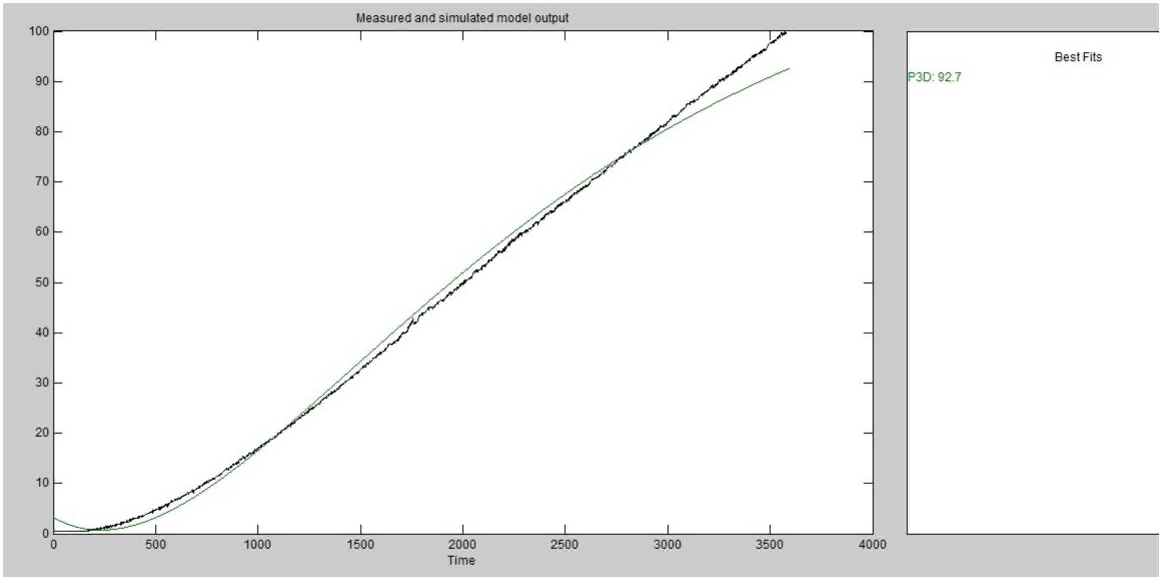


Figure 7.3: Open Loop Response of Second Order With Large Td

Chapter 8

Smith Predictor

Using the model obtained for system identification, insert the transfer function of the model to be simulated in the front panel of LabVIEW along with the delay and select appropriate PID settings to get the desired response. Mention simulation time in the front panel depending on the response.

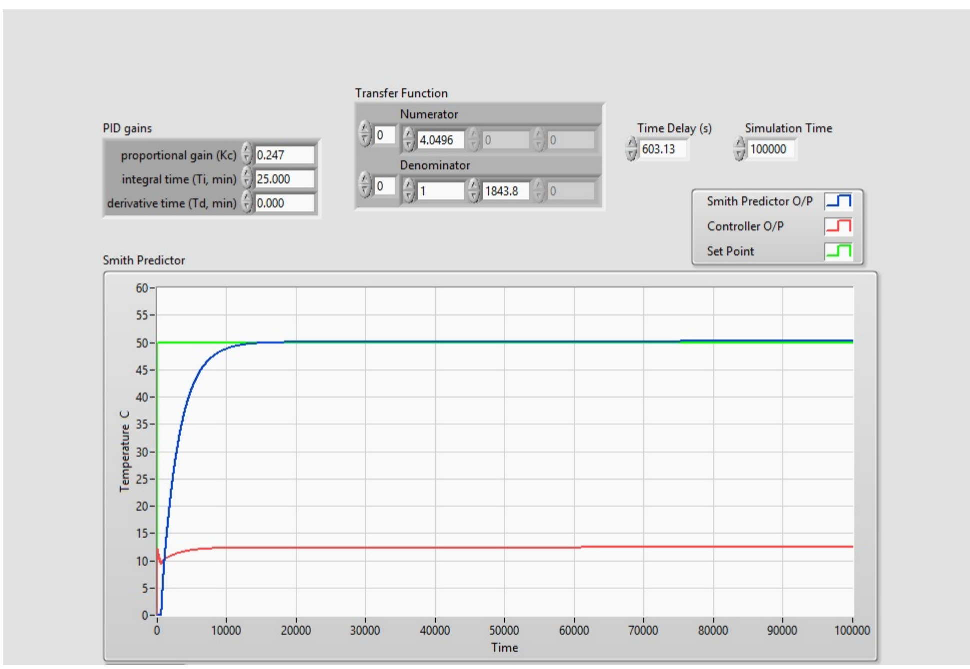


Figure 8.1: LabVIEW FrontPanel of Smith Predictor

8.1 Implementation of Smith Predictor

8.1.1 Second Order System

By placing the Second order transfer function and keeping PID settings as Kp=0.140 Ti=50 Mins Td=0 and simulation time as 100000Sec following responce was obained.

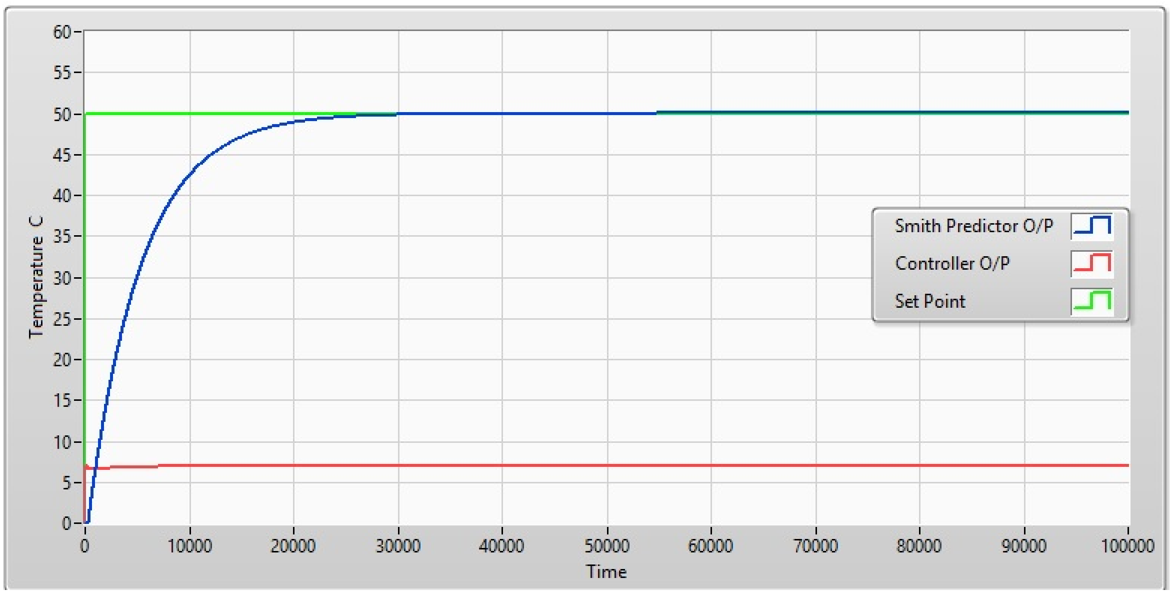


Figure 8.2: LabVIEW FrontPanel of Smith Predictor

From the above plot it can be observed that for second order system with Kp=0.140 Ti=50 Mins smith predictor (Blue) gives satisfacctory result as compared to PID (Red) which has a steady state error of 45.Rise time Tr of Smith predictor in above case is 12000 Sec and settling time Ts is 30000 Sec.

8.1.2 Second Order System With Small Time Delay

By placing the Second order transfer function and keeping PID settings as Kp=0.155 Ti=75 Mins Td=0 and simulation time as 100000Sec following responce was obained.

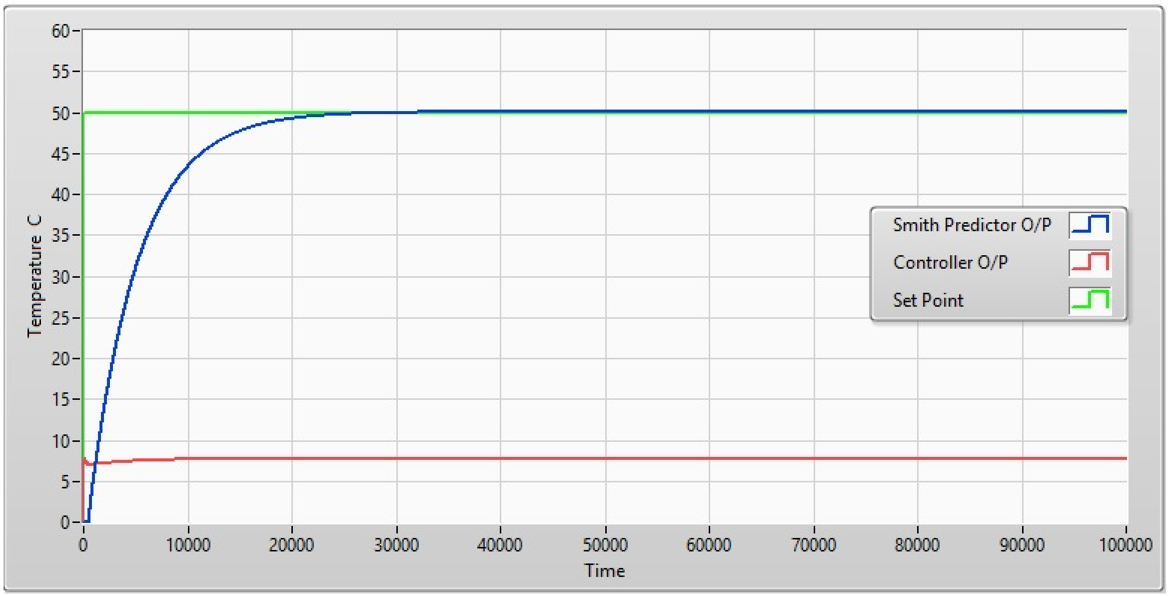


Figure 8.3: Simulation of Smith Predictor

From the above plot it can be observed that for second order system with Kp=0.155 Ti=75 Smith predictor (Blue) gives satisfacctory result as compared to PID (Red) which has a steady state error of 43.Rise time Tr of Smith predictor in above case is 10500 Sec and settling time Ts is 26000 Sec.

8.1.3 Second Order System With Large Time Delay

By placing the Second order transfer function and keeping PID settings as Kp=0.247 Ti=25 Mins Td=0 and simulation time as 100000Sec following responce was obained.

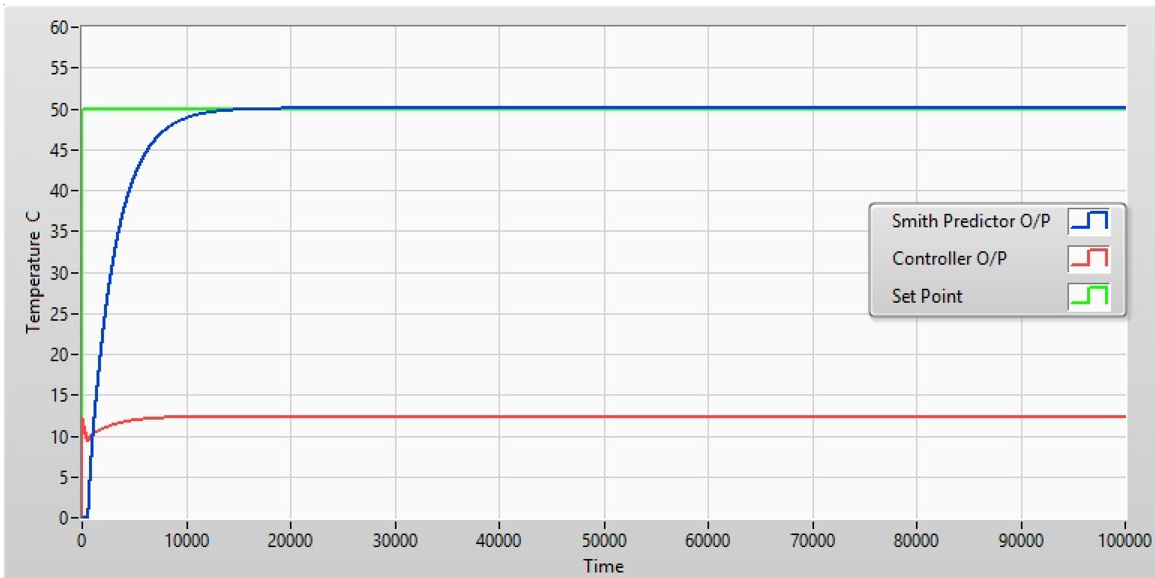


Figure 8.4: LabVIEW FrontPanel of Smith Predictor

From the above plot it can be observed that for second order system with Kp=0.247 Ti=25 smith predictor (Blue) gives satisfacctory result as compared to PID (Red) which has a steady state error of 43.Rise time of Smith predictor in above case is 7500 Sec and settling time is 14000 Sec.

8.2 Comparative Analysis

	Kp	Ti Min	Td Min
Second Order	0.14	50	0
Second Order With Small Td	0.16	75	0
Second Order With Large Td	0.25	25	0

From the above table it was concluded that each model gives satisfactory result only for particular PID settings and with any other PID settings it fails to give satisfactory result i.e. For second order system with small time delay, will give satisfactory result for the above mentioned PID settings and if the settings are changed results are unacceptable.

Thus it was concluded that smith predictor removes the time delay problem for individual processes but for the whole system with variable time delay every time the PID settings have to be changed depending upon the process. Smith predictor fails for variable time delay processes thus advance control algorithm like MPC should be implemented.

Chapter 9

Conclusion and Future Work

Successful integration of Backhoff EK-1100 PLC with TwinCAT software and 3rd party software like NI-LabVIEW. Implemented PID controller in NI LabVIEW using TwinCAT as data acquisition. After successful implementation of PID, comparative analysis was done on process with and without time delay keeping the same PID settings. System Identification using ident tools in MATLAB was carried out and models of different system were obtained. Once all the models were obtained next step was to implement Smith Predictor in NI LabVIEW and compare the results with PID. It was concluded that Smith Predictor gives satisfactory result as compared to PID for time delay systems but smith predictor fails for variable time system. Thus an advance controller like MPC should be implemented for such variable time delay processes.

Chapter 10

Bibliography

1. V.Jenifer Poorani, L.D.Vijay Anand, "Comparison of PID Controller and Smith Predictor Controller for Heat Exchanger", 2013 IEEE International Conference on Emerging Trends in Computing, Communication and Nanotechnology (ICECCN 2013).

2. Sonu Joseph, L.D. Vijayanand, "Dead time Compensating PID Controller Structure and Robust Tuning for Water Bath Process",(IJERT) Vol.3 Issue 1, January - 2014.

3. Nader N. Barsoum, Pin Rui Chin, "Ethernet Control AC Motor via PLC Using LabVIEW", Intelligent Control and Automation, 2011, 2, 330-339.

4. Shihua Wang, Bugong Xu and Qingyang Wang, Yun-Hui Liu, "Modified Smith Predictor and Controller for Time-Delay Process with Uncertainty", Proceedings of the 6th World Congress on Intelligent Control and Automation, June 21 - 23, 2006, Dalian, China.

5. M. Sbarciog, R. De Keyser, S. Cristea and C. De Prada, "Nonlinear predictive control of processes with variable time delay. A temperature control case study", 17th IEEE International Conference on Control Applications Part of 2008 IEEE Multi-conference on Systems and Control San Antonio, Texas, USA, September 3-5, 2008

6.SHAN Jiang-dong, WU Ge, TIAN Xiao-jian, "Study on large time-delay constant temperature control system based on TEC", The Journal of China

Universities of Posts and Telecommunications

7.Jian Wang, Shengjun Zhong, Xinguang Li, Fuli Wang, "Development of 20 Liter Spherical Explosion Test Apparatus Based on LabVIEW and OPC Technique", 2010 Chinese Control and Decision Conference

8. Steven W. Su, Hung T. Nguyen, and Q. P. Ha, "Laboratory Demonstration for Model Predictive Multivariable Control with a Coupled Drive System", 2010 11th Int. Conf. Control, Automation, Robotics and Vision Singapore, 7-10th December 2010.

9. Chemical Process Control by G. Stephanopoulos

10. $http://www.beckhoff.co.in/$

11. $http://pcbheaven.com/circuitpages/Voltage_Controlled_AC_Light_Dimmer/$

12. $http://www.ni.com/en-in.html$