SIMULATION ON DISTRIBUTED CONTROL SYSTEM TIME DELAY

By

SRI PRATHAYINI A/P ARUDRA

FINAL PROJECT REPORT

Submitted to the Department of Electrical Engineering
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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TRONOH, PERAK

May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Sri Prathayini A/P Arudra

ABSTRACT

One of the fastest growing market segments among control and automation technologies is the introduction and development of network control systems. Even though, fieldbus systems have been used for several years, functional and performance validation is an important issue addressed by fieldbus network design. Simulation support is needed for early functional validation and performance as an evaluation tool for the network design and operation performance analysis in early engineering stages. The delay time which is a random variable produced in the essence of the networked control system transmission process can greatly reduce the performance of control systems such as rising time and overshoot increasing, and situation where the control system become unstable. Therefore, this project briefly explains about the study on the fieldbus real time performance in term of time delay. Delay analysis on a designed cascaded control tank system with the case study of with and without controller have been performed to observe the severity of time delay on fieldbus system. The scope of study covered includes study on methodology to perform analysis on the fieldbus system of a plant using SIMULINK. From the findings, it can be observed that induced delay in complex fieldbus system is very prominent. Complex plant system has a high network delay and response time. Thus, these drawbacks can be overcome using simulation environment to forecast system behaviour and find the best suited network solutions beforehand to minimize engineering and hardware costs.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Fieldbus is the lowest industrial network level in the computer communication hierarchy of distributed process control systems. The network is a bi-directional and multi drop where serial bus is used to link isolated field devices, such as controllers, transducers, actuators and sensors. Many different protocols such as PROFIBUS, LON, CAN, WorldFip have been developed for particular application areas. Among those, PROFIBUS is one of the international generic standards of fieldbus. It is now widely used in manufacturing automation and process industrial automation, building automation and other fields.

Task scheduling of the shared medium has become the most common research lately and fieldbus real time performance is identified to be an important problem that the control system is facing. One of them would be the delay time. The delay time is usually a random variable which is produced in the essence of networked control system transmission process. This delay reduces performance of system in varying degree and can cause instability of system. Latency is mostly caused by two types of delay which is computing delay by the sensors, actuators and controllers, and the network induced delay caused by transmission delay. In order to evaluate these control structures explicit, simulation model will be a useful tool.

This paper proposes using SIMULINK tools to simulate and analyse task scheduling. SIMULINK runs in the MATLAB environment and is used for simulation and analysis of dynamic system packages which provides a visualization of the environment and a number of system simulation libraries. Therefore simulation would reflect the real implementations to obtain reliable information of the network.

1.2 Problem Statement

The problem statement proposed in this project would be the simulated network induced delay of networked control system which reduce the stability and control performance of fieldbus system. Therefore this paper is to conduct a delay analysis on the fieldbus cascaded type of system.

1.2.1 Problem Identification

Plants usually require higher control performance, better system reliability, and greater ease of plant operation. These requirements necessitate substantive improvements in plant automation. If the fieldbus network is inappropriately designed, network-induced delays of real-time data could exceed their pre-determined limitations, and the performance requirements of control systems in the plant cannot be satisfied. The performance measurement of tasks which takes place in network control system would be based on the delay of system execution which is the control response time. Delay of networked control system can greatly reduce the performance of control system. Thus, the performance of fieldbus system must be carefully evaluated before the fieldbus network is implemented in the plants.

1.3 Objectives

Based on the problem statements above, the objective of this project is to perform simulation on fieldbus control network tasks and determine the following:

- To study the real time control performance of fieldbus control system.
- To perform delay analysis of fieldbus networked control system.

1.4 Scope of Study

- Study of fieldbus network simulation using SIMULINK.
- Study on methodology to perform analysis on the system performance of fieldbus system of a plant using SIMULINK.

1.5 Significance of Study

The result of this study will be evidence that SIMULINK can be used to apply control and conduct performance analysis on fieldbus system to obtain real time performance with reduced network induced delay.

1.6 Relevance and Feasibility of the Project

This project is relevant to the author's field of majoring since fieldbus system is one of the focus areas in industrial automation and control system. Moreover, many studies and research on fieldbus networks performance in the distributed computer control are on-going due to the high industrial demand. The project is also in phase with the current requirement of plant management for higher control performance, better system reliability along with greater ease of operation and management of complex system. In this project, the author has applied plant process control system and industrial automation control system theories to study the operational method of fieldbus system and investigate the effects of network induced delay of fieldbus network. The author has selected simulation method with SIMULINK to perform functional and performance validation on the network in order to obtain the best suited network solutions.

The project is feasible since it is within the scope and time frame. The author has planned to complete the research and literature review by the end of the first semester and conduct the methodology on performance analysis with SIMULINK on the final semester. Author plans to dedicate the first eight weeks of final year project II (FYP II) to design the SIMULINK model blocks of fieldbus system of a plant process and analyse its performance whereas the next six weeks the author plans to experiment ways to reduce network induced delay and obtain the best performance and response time.

CHAPTER 2

LITERATURE REVIEW / THEORY

THEORY

This paper focuses on the simulation of fieldbus control performance in terms of network induced delay. To perform the studies and analysis on this project, the author had decided to design simulation of combined three basic closed tank systems and observe their performance. In order to conduct the study, below theories are essential element needed before hand.

2.1 Fluid flow System

Fluid flow systems are very familiar in process control. These type of systems involve components like:-

- Process : mixing or blending process, liquid holding tanks
- Measured value: level, flow, composition (use of transducers)
- Actuators: valves and pumps

Taking the single tank system (Figure 2.1) which will be used in this project for performance analysis, the above theories can be explained.

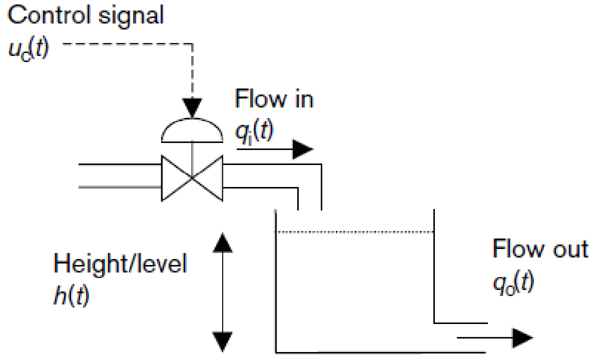


Figure 2.1: Single Tank System

Figure 2.1 shows a tank containing liquid. The flow of liquid that flow into the tank is controlled by a valve. The control input signal to the valve is in mA units which is an electrical signal converted into a pressure signal. This pressure is applied to the valve and changes the valve stem position (in mm). The valve position indicates the amount of liquid flow passing through the valve into the tank. The height of liquid in the tank is measured by a transducer (gauge pressure) which produces an output in mA.

Process: The process represents the change in level of the liquid in the tank. The input signal is the flow into the tank, qi(t) (in m3/s). The output signal of the system is the height of liquid in the tank. Combining these give the process block diagram below:-

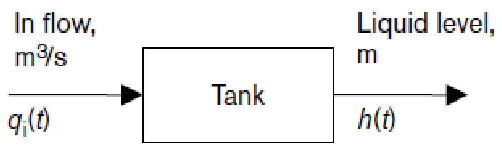


Figure 2.2: Process block Diagram

Transducer: The tank system needs measuring of the height of liquid in the tank. The transducer in the system does not measure level directly, but measures pressure.

From,

$$\text{pressure} = \text{density} \times g \times \text{head of liquid}$$

and the value for the head, or level of liquid, can be calculated. The pressure measurement transducer will then convert the gauge pressure reading (pressure reading relative to atmospheric) to an equivalent electrical current signal (in mA). The transducer block diagram is shown in figure 2.3 .

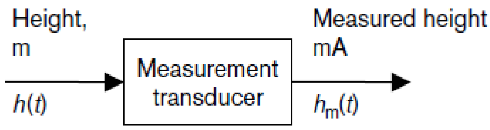


Figure 2.3: Measurement Transducer

Actuator: The actuation system 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). The actuator block diagram is given in figure 2.4.

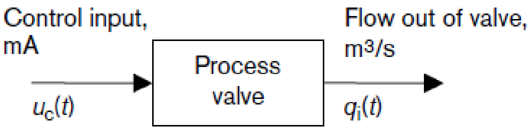


Figure 2.4: Actuator block

By combining the Actuator–Process–Transducer block diagrams we find the total process block diagram can be represented by Figure 2.5.

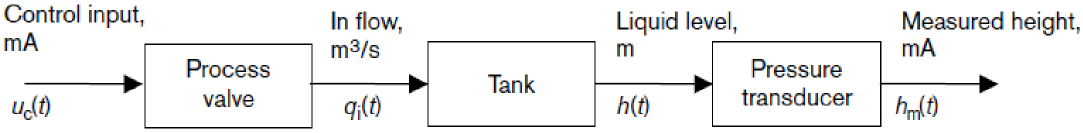


Figure 2.5: Combined block diagram for fluid flow system

In order to apply a control for the above system, PID controller can be used.

2.2 PID controller

A (PID controller) is a control loop feedback mechanism (controller) widely used in industrial. The difference between a measured process variable and a desired set point is called "error". A PID controller calculates an "error" and attempts to minimize the error by adjusting the process control inputs.

The PID controller calculation (algorithm) involves three separate constant parameters, and is accordingly sometimes called three-term control which is the proportional, the integral and derivative values, P, I, and D. Accordingly, these values can be interpreted in terms of time. P of the controller depends on the present error, I would be the accumulation of past errors, and D is the prediction of future errors, based on current rate of change. A control valve is used to adjust the process such as the position of a control valve from the weighted sum of these three actions via.

The three parameters in the PID controller algorithm can be tuned, to provide control action designed for specific process requirements. The response of the controller can be viewed in terms of the responsiveness of the controller to an error. The degree to which the controller overshoots the set point and the degree of system oscillation is included as response. It should be noted that the use of the PID algorithm for control does not guarantee optimal control of the system and its stability.

Some applications may require using only one or two actions such as P, PI or PD to provide the appropriate system control. This can be achieved by setting the other parameters to zero. A PID controller will be called a PI, PD, P or I controller in the absence of its respective control actions. PI controllers are quite common, since derivative action is sensitive to measurement noise, whereas the absence of an I term may prevent the system from reaching its target value due to the control action.

LITERATURE REVIEW

Fieldbus system as one of the most vibrant technology today is irreplaceable with any other process control domains. Fieldbus simulation objectives are for the communication network to be able to meet functional requirements, support real time constraints and to identify optimal parameters for the performance. Real time constraints as the important criteria highly depend on the time delay in fieldbus control system.

According to Fang He and Kai Guo on their delay analysis of networked control system, the delay is produced in the essence of transmission process of information brought by networked nodes form the task, after all floors of the agreement package through network to another. There are mostly two types of delay which is the computing delay by the equipments such as sensors, controllers and actuators and shared communication and transmission delay caused by the collision occurred in the network called network- induced delay. Delay of computing is relatively smaller than sampling period where it is negligible but network induced delay is impossible to ignore [1]. Factors that cause network- induced delay is as following [2]:-

- The delay of data packet queue waiting – the time waiting for network usage when network is busy and data packets collided.
- The information delay – the time for sending information packages to entering the queue.
- The delay of transmission time – the time spend in the actual transmission of data packet, it depends on the size of data packets, network bandwidth and transmission distance.

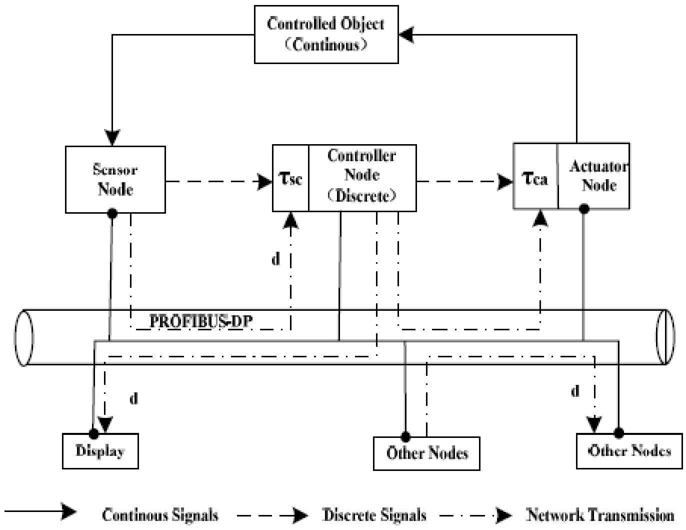


Figure 2.6: Network Delay (He & Guo, 2008)

There are several types of network simulation tools. Many researchers have used the various network simulation tools and explained their differences and features. It is not easy to evaluate which tool is better than the others because every simulator has its own characteristic features. Among the approaches that have been made earlier by researchers using different software to achieve the design network goals on fieldbus has been simplified in the table of appendix 2. The table includes overall literature review been used in this project as reference.

CHAPTER 3

METHODOLOGY

3.1 Project Work

The assessment on the fieldbus system performance will be conducted by designing a control tank system. In order to support the assessment designing process, several studies and experiment on the PID controller which is being used to control the system will also has been conducted. Control tank system is an important element of any plant process facility. Different types of tanks or vessels are being used in different process plants. Such tanks like storage tanks, pressure tanks, mixing tanks and custom tanks have different structure and functionality depending on the purpose of the facility where they are being used. However, this project uses custom tanks systems to achieve the project objective and conduct delay performance analysis. The basic of 3 types of tanks will be used in this project as in Figure 3.1, 3.2 and 3.3. All these three types of tank formation will be then combined to design a more complicated tank system to represent the system in industrial plant. This would be necessary to project the complexity of plant system which uses fieldbus system.

3.1.1 Single Tank System

Single tank system would be the basic formation of the other tank systems. In this single tank system, the height of the liquid in the tank will be measured as output and the liquid inflow from valve into the tank would be the input for system. A control would be implemented in this tank system where the inflow valve opening will be controlled by the liquid level in tank. As for the case scenario, when liquid level in tank reaches its maximum level, the level transducer at the tank would send electric signal to the PID controller and the controller would send pneumatic signal to the inflow valve to control the opening of valve head to avoid overflow. This would work as a close loop system. Figure 3.1 shows the single tank system.

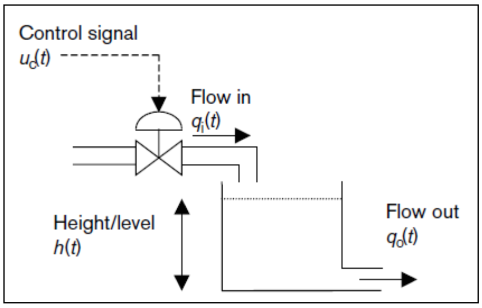


Figure 3.1: Single Tank system

3.1.2 Split Tank System

Split tank system would be the combination of two single tank systems. In this system, there will be one input and two outputs. The input would be Qin from the inflow valve entering the first tank. The outflow of tank one will act as the input for tank 2. The output for the system would be tank 2 level which is H2. A control can be applied for this tank system with two cases if it works individually. The first would be when H1 have reached maximum level and H2 have not reached its maximum level. In this condition, the head opening for valve Qin would remain the same. The second case is when both H1 and H2 have reached their maximum height, the PID controller would send electrical signal to control the percentage of Qin valve head opening.

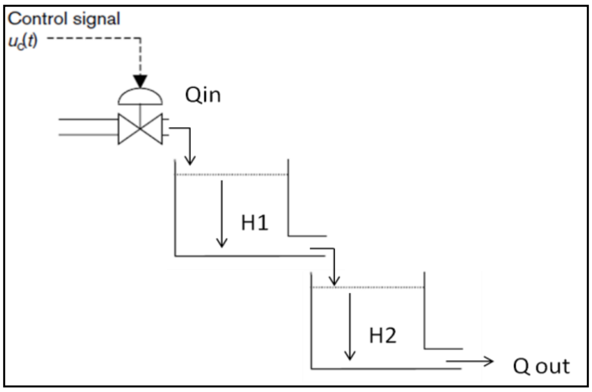


Figure 3.2: Split tank System

3.1.3 Custom Tank System

Custom tank system is a combination of 3 single tanks. In this system there would be two inputs, Q1 and Q2 and one output, Q5. Therefore there will be three level transducers and two input flow valve. The output flow Q3 and Q4 will be input for the second tank. If a control is to be implemented to this system, the conditions are as below.

- First condition: H1, H2 and H3 have not reached its maximum level – PID controller will not send any signal to apply changes to valve head opening.
- Second condition: H1 and H3 reached maximum level, H2 still have not reached maximum level – PID controller send signal to minimize the valve head opening of Q1 and Q2 for smooth flow.
- Third condition: H1, H2 and H3 have reached its maximum level – PID controller send signal to close the valve head opening of Q1 and Q2 to shut the flow into tank 1 and 3.

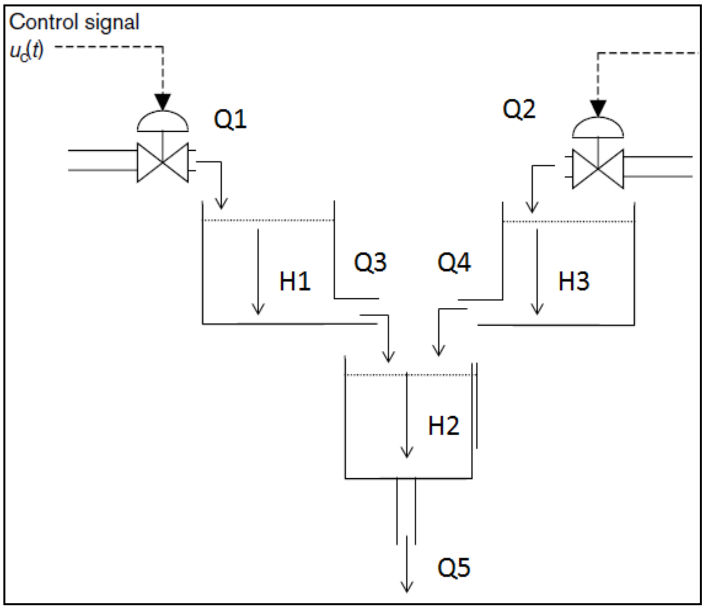


Figure 3.3: Custom Tank System

3.1.4 Combined tank system

Combined control tank system uses the combination of two different type of control tank system mentioned above. Custom tank and split tank will be combined as shown in Figure 3.4. This combined system consists of two inputs and three outputs. The final output measured will be H5 meanwhile the other outputs measured would be H3 and H4. If a controller is to be applied, the output of H5 will be used as feedback for controller to perform its corrective measures.

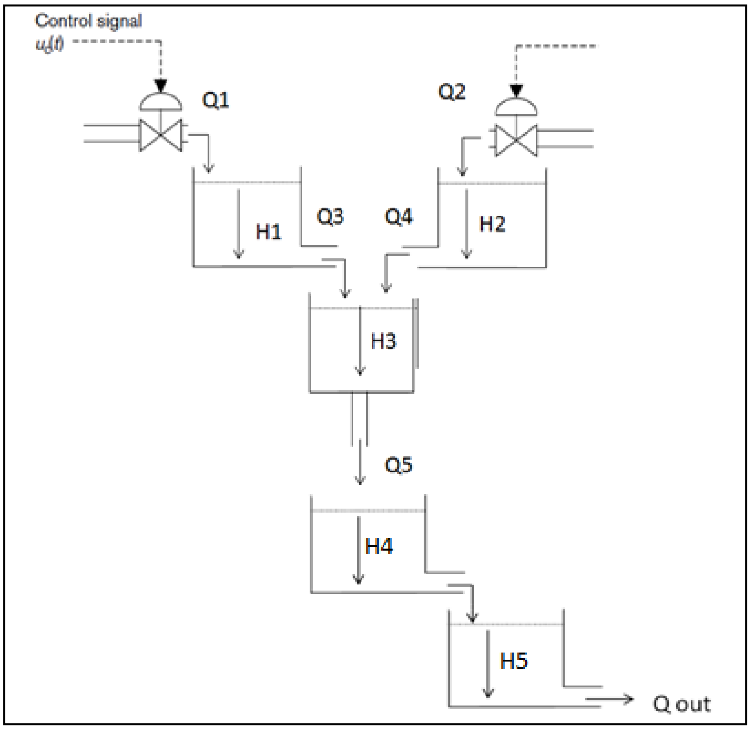


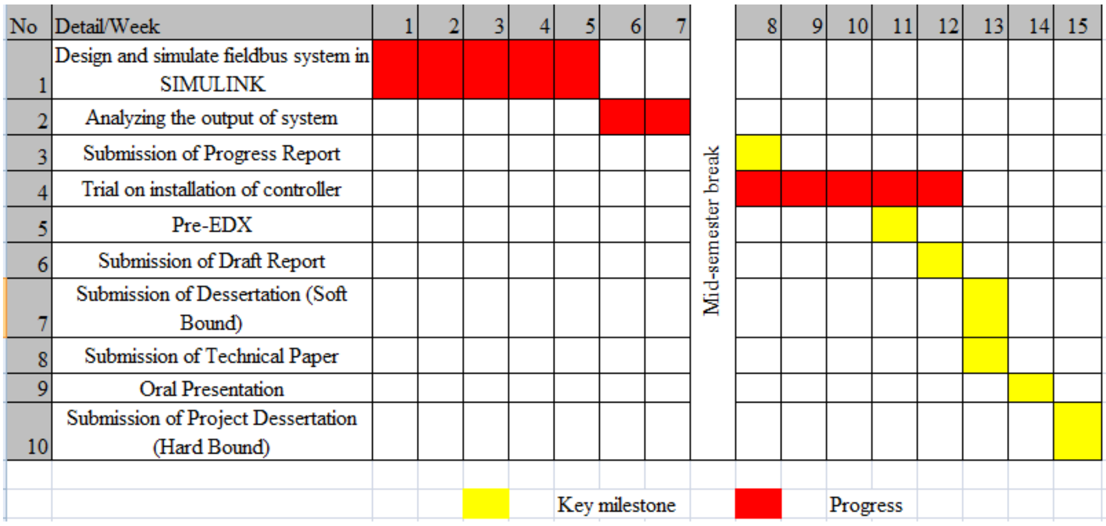
Figure 3.4: Combined Tank System

3.2Project Flow Chart

The project execution flow chart (Appendix 1) has been drafted to show the procedures and steps to be taken throughout the project research period. This flow chart however only covers the current objectives of the research. Any further additional objectives added will have the flow chart modified.

3.3 Gantt Chart

Table 3.1: Gantt chart and key milestone for FYP 2



3.4 Tools and software required

Table 3.2: Tools and Software required

Software	1) MATLAB/ SIMULINK
	2) Microsoft Word

SIMULINK would be the main software tool used in this project to design mathematical model blocks of fieldbus system representing closed tank system. The performance analysis, testing and designing phase of this project needs the aid of SIMULINK to be completed. On the other hand, Microsoft Word is needed for the author to outline the preliminary report, proposal defence, interim report, dissertation and other paper works which is involved along in this project.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Data Gathering and Analysis

4.1.1 Case 1: Random variable controller

The simulation on fieldbus system control performance has been conducted on a combined control tank system of Figure 3.4. The system has been tested with a random variable controller as a first approach. From the simulation of the combined tank system, the output graph H3, H4 and H5 have been obtained. The output graph is then compared with input signal waveform to perform the delay analysis. The output graph H3 is as shown below in Figure 4.1.

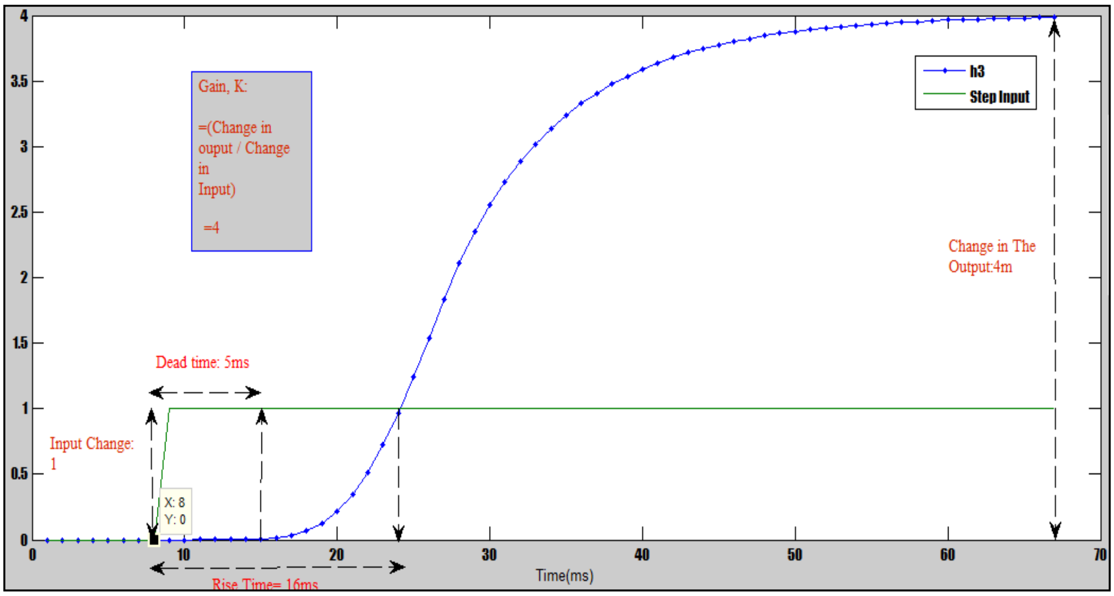


Figure 4.1: Tank 3 output graph

From the above graph, it can be observed that for an input step change of 1, the output change that was obtained is 4. Therefore the gain calculated from the graph above is 4. From the analysis of the input signal and output signal H3, the dead time which is the delay of the system is 5ms and the rise time of the output graph is 16ms. Figure 4.2 shows H4 output graph which is the second level output of the system.

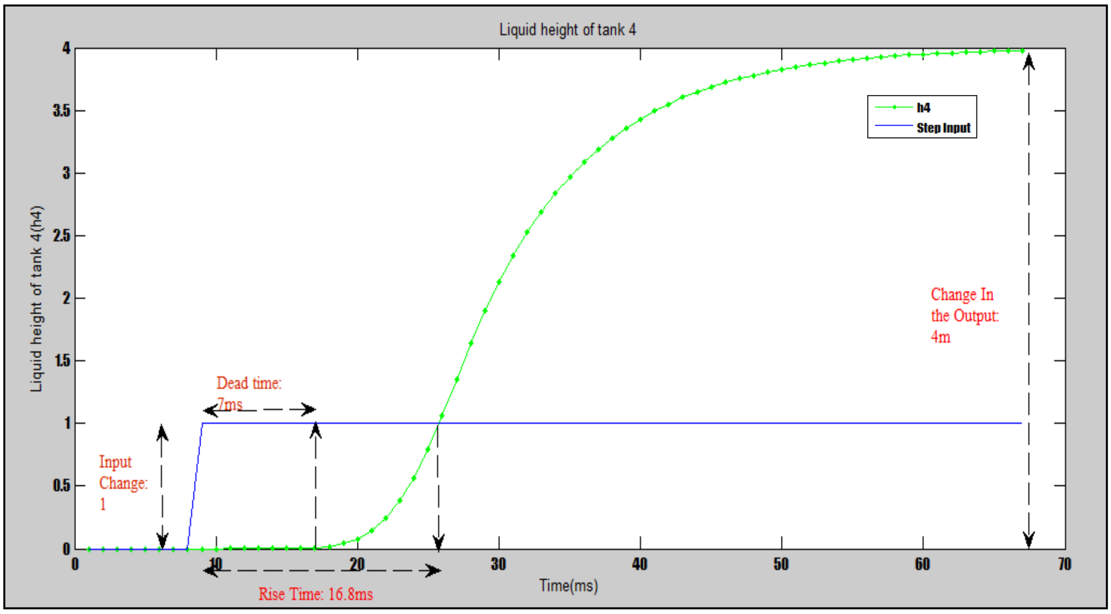


Figure 4.2: Tank 4 output graph

For output graph H4, the gain of the output is the same as H3 because of the constant value in the input and output changes. The delay time and rise time for output H4 is 7ms and 16.8ms accordingly. Delay time and rise time of H4 have increased compared to H3.

As for H5 which is the final output of the combined tank system, the output graph is as shown in Figure 4.3. H5 output waveform has the highest delay time and rise time compared to H3 and H4 which is 9ms and 18ms. It also maintains the same gain as H3 and H4.

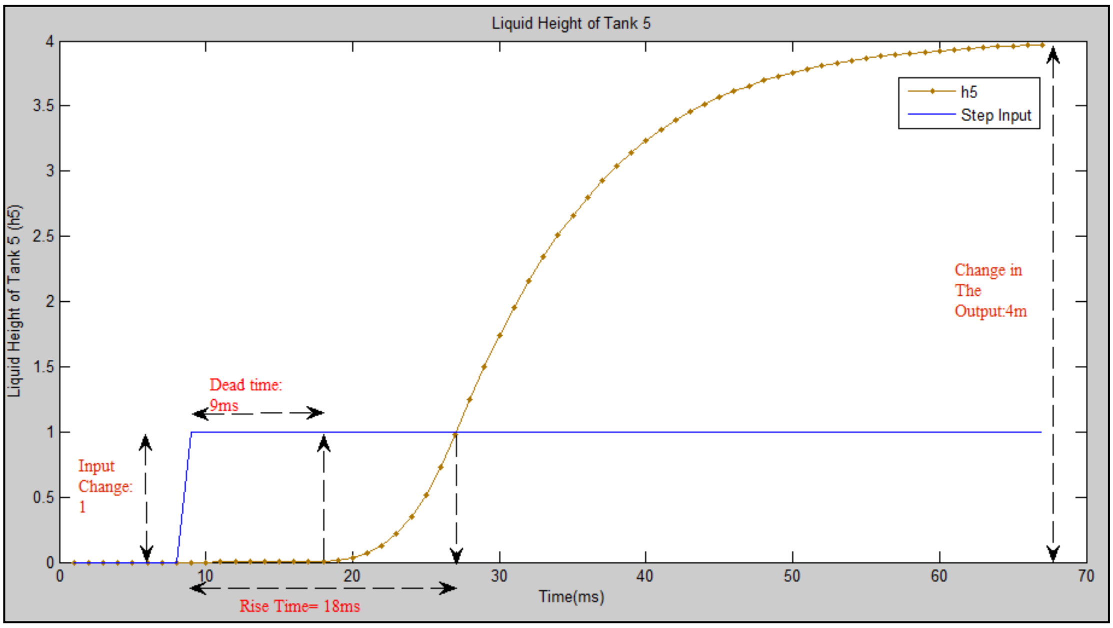


Figure 4.3: Tank 5 output graph

Based on the output data analysis of tank 3, tank 4 and tank 5 and their comparisons, it can be observed that complexity of a fieldbus system determines its network induced delay. Plants that operates on large number of independent devices would generate high time delay. This also indicates a higher response time. Rise time and delay time would also affect the settling time in the system. Settling time is the time consumed for the output graph to reach stability. The higher the rise time and delay time, the greater would be settling time and the later the output graph would reach stability.

4.1.2 Case 2: With tuned PI and PID Controller

The above combined cascaded tank is then installed with well tuned controller to include control function which is to control the tank levels individually. The tank was installed with two type of controllers which is the PI and PID controller. These controllers were chosen among others because of its optimal functional characteristics with control tank system. The output response is measured for tank 3, 4 and 5 as similar to case 1 without controller. The output response obtained is as shown below.

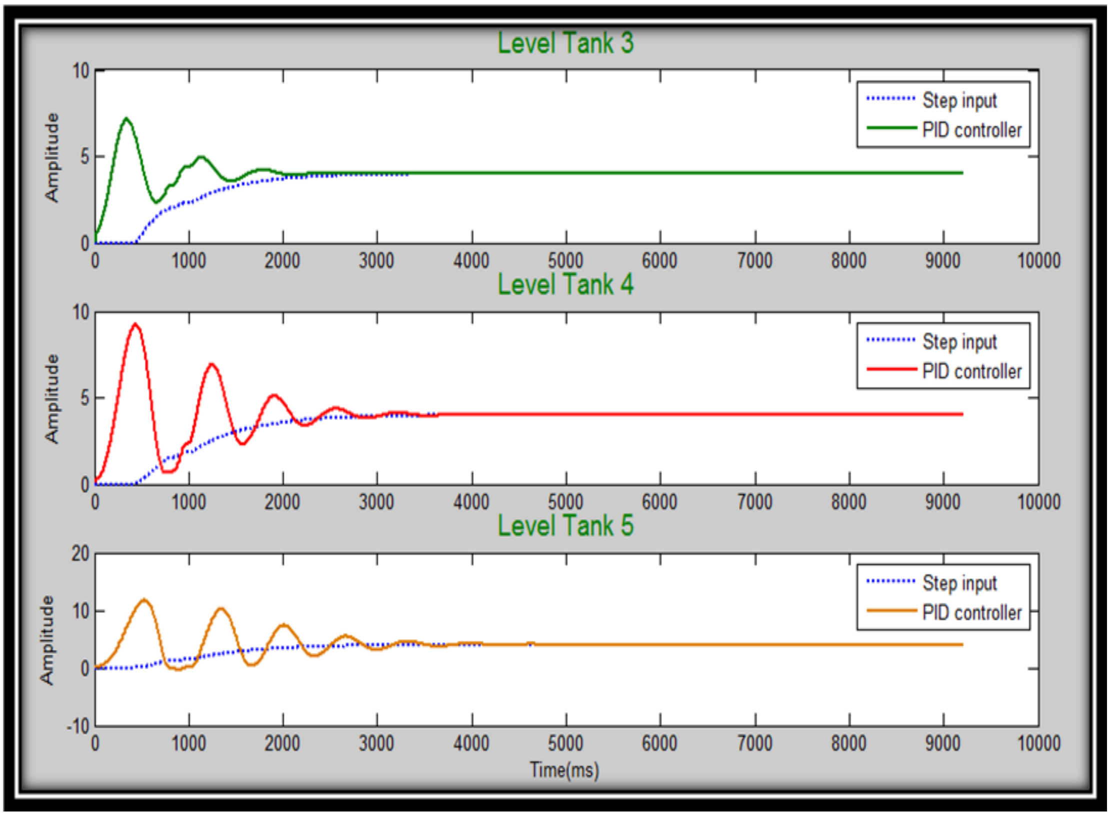


Figure 4.4: PID controller output for level tank 3, 4 and 5

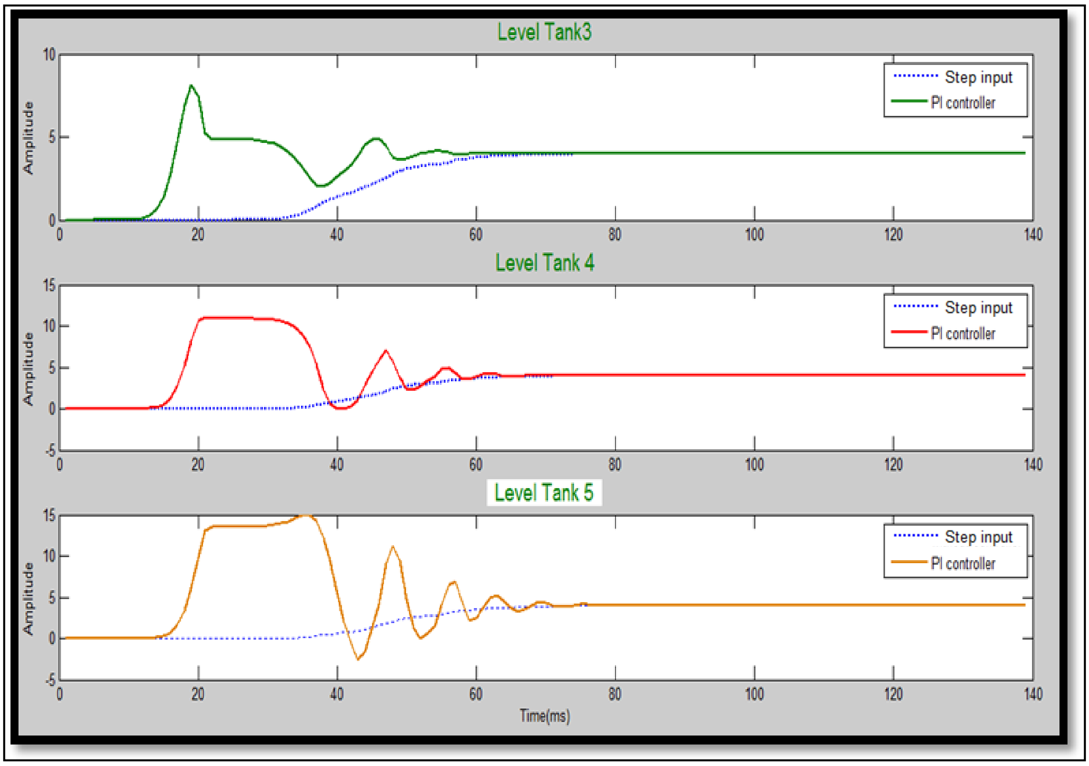


Figure 4.5: PI controller output for level tank 3, 4 and 5

Figure 4.4 and 4.5 above shows the PID and PI controller output graph for level tank 3, 4 and 5. An analysis has been made for the graph above and tabled as in the next page.

From the table, we can observe that all the output generated with PI and PID controller has a stable output and zero steady state error. However, PID controller produces a higher rise time and settling time to reach stability compared to PI controller. For the overshoot, PID controller has a controlled overshoot compared to PI controller. Overshoot represents a distortion of the signal and often is associated with settling time, how long it takes for the output to reach steady state.

Table 4.1: PI and PID controller output analysis for level tank 3, 4 and 5

	PID Controller	PI Controller
Tank 3	Rise Time = 180ms Overshoot = 7 Settling Time = 2600ms Steady state Error = zero Stability = Stable	Rise Time = 15.5ms Overshoot = 8 Settling Time = 63ms Steady state Error =zero Stability = Stable
Tank 4	Rise Time = 230ms Overshoot = 9.5 Settling Time = 3400ms Steady state Error = zero Stability = Stable	Rise Time = 16.5ms Overshoot = 11 Settling Time = 70ms Steady state Error =zero Stability = Stable
Tank 5	Rise Time = 250ms Overshoot =11.8 Settling Time = 4450ms Steady state Error =zero Stability = Stable	Rise Time = 18ms Overshoot = 15 Settling Time = 78ms Steady state Error =zero Stability = Stable

In general, the output performance generated by controller systems depends on the controller that being used along with its selection of parameters. By tuning the three parameters in the PID controller algorithm, the controller can provide control action designed for specific process requirements. There are several methods that can be used to tune controllers such as manual tuning, auto tuning variation, Ziegler Nicholas method and also Cohen coon method. For this project, the best output generated from the optional methods has been selected. Therefore, the advantages and disadvantages of above methods id identified in the first place. The advantages and disadvantages of the tuning methods mentioned above is outlined as below.

Table 4.2: Advantages and disadvantages of controller tuning method

Methods	Advantages	Disadvantages
Manual tuning	• No math required; online.	• Requires experienced personnel.
Auto tuning variation	• can be determined without disturbing the system and tuning values for PID	• only work on systems that have significant dead time or the ultimate period, P_u
Ziegler Nicholas closed loop method	• Easy experiment; only need to change the P controller • Includes dynamics of whole process, which gives a more accurate picture of how the system is behaving	• Experiment can be time consuming • Can venture into unstable regions while testing the P controller, which could cause the system to become out of control
Cohen coon method	• Used for systems with time delay. • Quicker closed loop response time	• Unstable closed loop systems. • Can only be used for first order models including large process delays. • Approximations for the K_c, τ_i, and τ_d values might not be entirely accurate for different systems

From the above table, it can be observed that Cohen coon method is not suitable for tuning the controller parameter in this paper. This is due to the disadvantages in Cohen coon method which can only be used for first order modelling which is contradicting with our designed cascaded tank system which is a higher model. As a second approach, manual tuning and Ziegler Nicholas method was chosen to be used. From the attempt on the methods, manual tuning is found to be a very complicated way of tuning the controller which generates inaccurate result without the assistance from experienced personnel. For the Ziegler Nicholas method, the below calculation was done and implemented. The generated output waveform is found to be less accurate then the auto tuning variation method provided by the SIMULINK software. Therefore, the auto tuning variation method was used to tune the controller PI and PID in this paper.

4.1.2.1 Ziegler Nicholas method

The Ziegler Nicholas method tuning procedure is as below:

- First, remove the integral and derivative action. Set integral time (T_i) to 999 or its largest value and set the derivative controller (T_d) to zero.
- Then, a small disturbance was implemented in the loop by changing the set point. The proportional parameter *Kp* was adjusted by increasing and/or decreasing, the gain until the oscillations shows constant amplitude.
- The ultimate (or critical) period *Pu* and ultimate gain *Ku* of the sustained oscillation was measured.
- The following parameter was then inserted on below table and *Kp, Ti* and *Td* was calculated and inserted in the software for simulation.

Table 4.3: Ziegler Nicholas Closed Loop method Table

	Kp	Ti	Td
P	0.5Ku	∞	0
PI	0.45Ku	Pu/1.2	0
PID	0.6Ku	Pu/2	Pu/8

Measured,

Ku= 3.5,   Pu= 10msec

For PID,	For PI,
Kp= 0.6Ku = 0.6(3.5) = 2.1	Kp= 0.45Ku = 0.45(3.5) = 1.575
Ti= Pu/2 = 5msec	Ti= Pu/1.2 = 8.333msec
Td= Pu/8 = 1.25msec	

4.1.3 Number of controllers

Upon conducting simulation on the above designed cascaded closed tank system, the influence of number of controllers on the performance of fieldbus system also was investigated. For this purpose, simulation of designed cascaded tank system with varying number of controllers have been experimented. The first case was with single controller controlling the whole system to ensure level tank 5 does not exceed its maximum height. In the second case, the system was experimented with a single controller controlling each tank individually. In the final case the system was experimented with multiple controllers (two or three controllers). Results for above mentioned cases were outlined as below.

4.1.3.1 Single controller

The idea of single controller being applied to the designed cascaded control tank is as shown in Figure 4.6. The output response obtained for this case, is as shown in Fig 4.7. From the output, it can be observed that the output generated has an increasing fluctuation, where it did not show indications of reaching stability. Therefore the output obtained is unstable with only one controller.

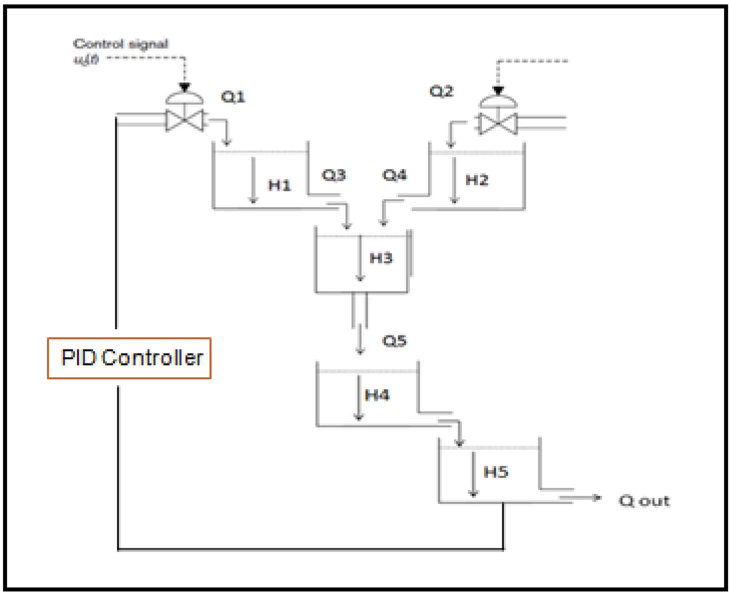


Figure 4.6: Single controller

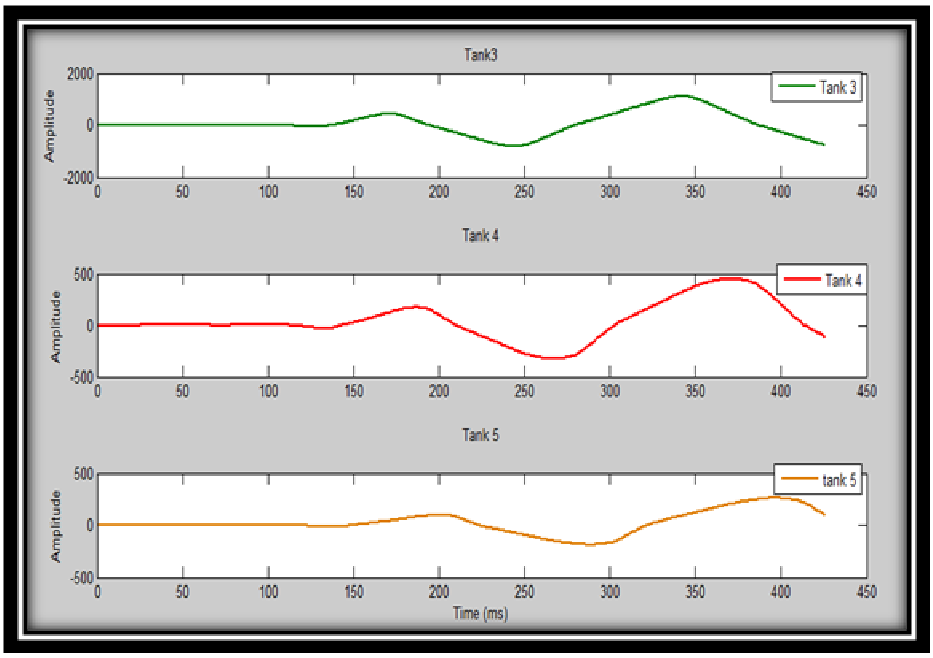


Figure 4.7: Output for Single controller

4.1.3.2 Controller at each tank

As for the second case, a single controller was used to provide control action to each tank individually. Therefore, the controller was connected to all tanks using the sum block in SIMULINK. Even though, only one controller has been used, control action was implemented at each tank to control their respective tank levels to avoid overflow. Figure 4.8 shows details on how control action was implemented at each tank. The output for this case is as shown in figure 4.5 where it was selected to be used for case 2 delay analysis. For further information on the output response performance, table 4.1 above can be used as reference.

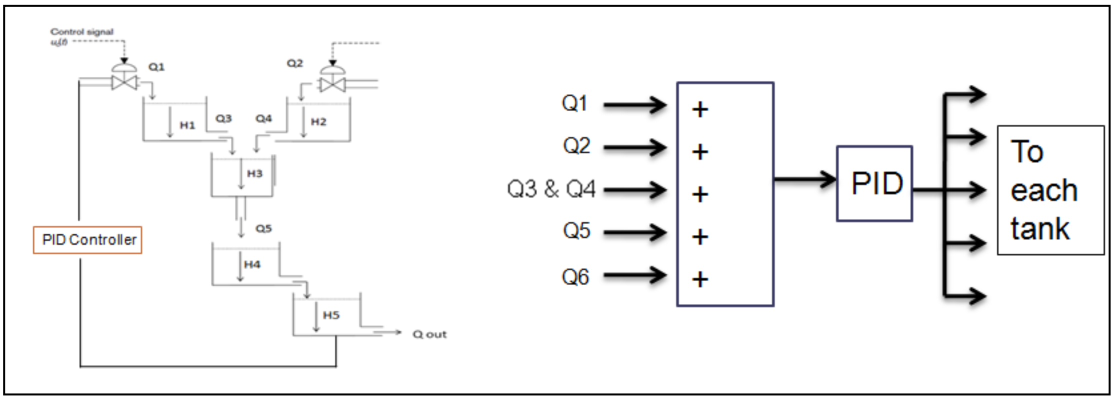


Figure 4.8: Output for Single controller controlling each tank

4.1.3.3 Multiple controllers

For experimenting the case with multiple controllers, the system was connected to two controllers as shown in figure 4.9. From the figure, it can be seen that the output of tank 3 was used to control input Q1 and Q2 with the first controller. Second controller was positioned in order to control the level of tank 5 by adjusting the input Q5. The output obtained for this case scenario is shown below in figure 4.10. Output generated from this case has a better performance compared to the first and second case in term of stability, less overshoot, less settling time and higher rise time. Therefore, plants with complex systems is advisable to use more controllers for better performance. These investigation results proves that, number of controllers also plays an important role in the performance of fieldbus system to guarantee minimum delay.

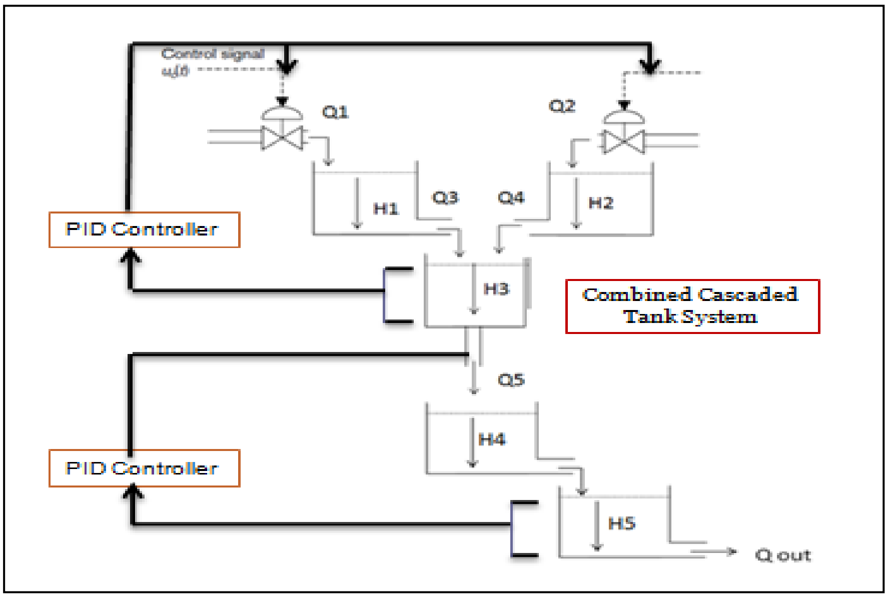


Figure 4.9: Multiple controller

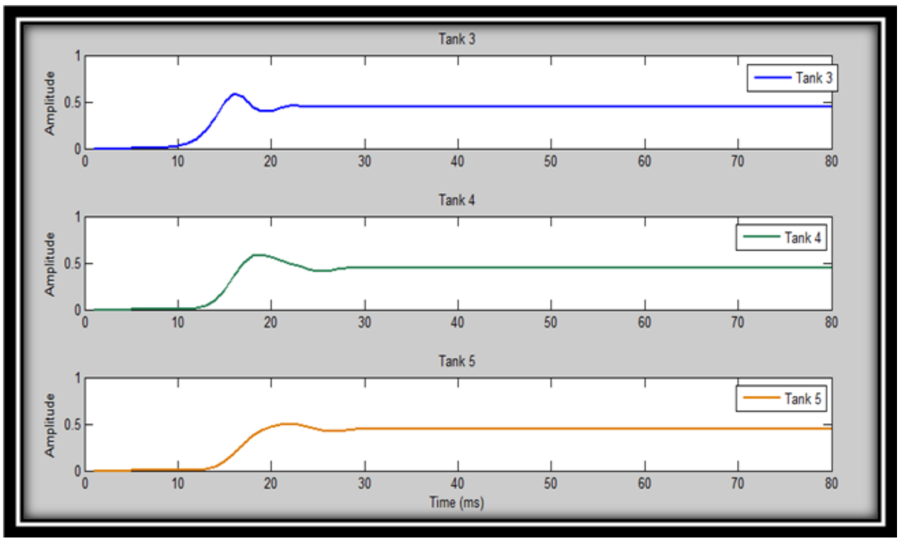


Figure 4.10: Output for multiple controller

4.2 Modelling

In order to obtain the output graph above, simulation had been done using SIMULINK on figure 3.4. The model blocks used in the simulation were taken from the MATLAB library to represent the plant components. The choice of block models solely depends on the mathematical equation formed from the tank systems. Block diagram used for simulation of combined tank is as shown in Appendix 3.

The combined tank system which is used in this paper work is formed from split tank system and custom tank system. Therefore the mathematical equation and the model blocks for the system are as shown below.

Single Tank system:

$$\frac{dH}{dt} = \frac{Qin - k\sqrt{H}}{A}$$

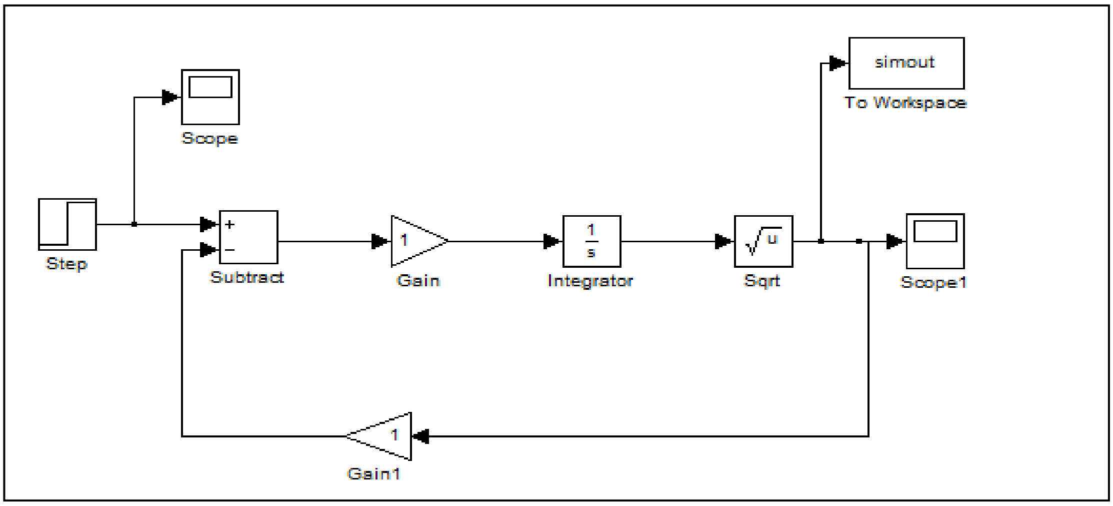


Figure 4.11: Single tank system model

Split Tank system:

$$\frac{dH1}{dt} = \frac{Qin - k1\sqrt{H1}}{A1}$$

$$\frac{dH2}{dt} = \frac{k1\sqrt{H1} - k2\sqrt{H2}}{A2}$$

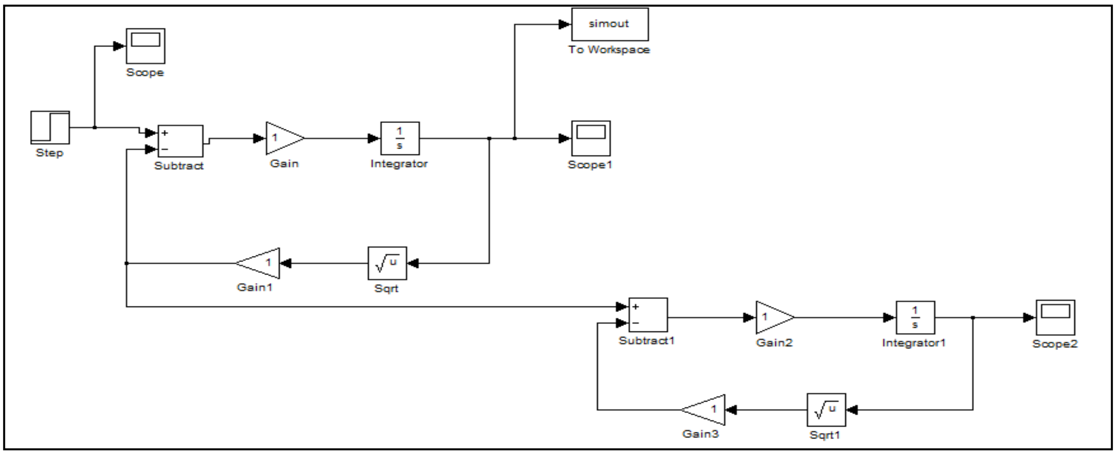


Figure 4.12: Split tank system

Custom tank system:

$$\frac{dH1}{dt} = \frac{Q1 - k1\sqrt{H1 - H2}}{A1}$$

$$\frac{dH3}{dt} = \frac{Q2 - k3\sqrt{H3 - H2}}{A3}$$

$$\frac{dH2}{dt} = \frac{-K2\sqrt{H2} + K1\sqrt{H1-H2} + k3\sqrt{H3 - H2}}{A2}$$

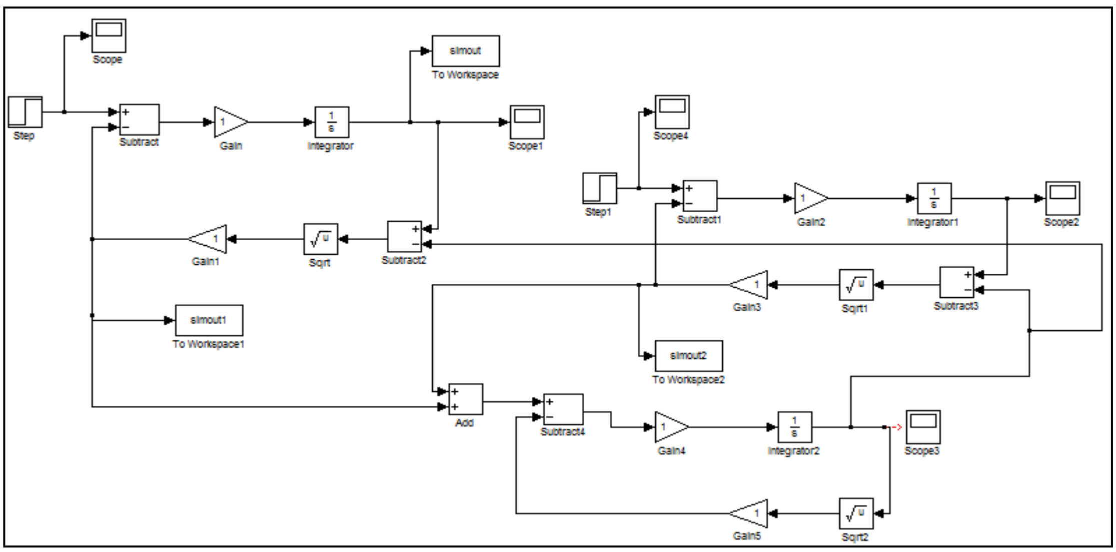


Figure 4.6: Custom Tank System

4.3 Finding

In the Data Gathering and Analysis section, analysis was divided into two sections of case 1 with a random variable controller and case 2 with a well tuned PID controller. The designed cascaded tank output is observed from tank 3, 4 and 5. Tank 5 indicates a more complex system followed by tank 4 and tank 3. The analysis for case 1 shows that the rise time and delay time increases with the complexity of the system. Increase in these parameters, will lead to latency in obtaining information at the output and also lead to reduced speed in the implementation of input changes. Therefore in real industry, applications such as alarms and system notification will face reduced efficiency.

As for case 2, the simulation is conducted with a PI and PID controller to obtain the best generated output. In this case, the level of each tank will be controlled by a PID controller to ensure the liquid height in tank does not exceed the maximum tank level. PID controller is not needed to be applied for each level individually, however sum block in SIMULINK can be used to simplify this task with the use of only one controller to control each tank level. In the case where only tank 5 level is needed to be controlled with the step input at Q1 and Q2 valves, at least two controllers are needed because of the complexity of the plant system. Therefore, the usage of multiple controllers can also contribute better performance of fieldbus system.

From the output of both controllers, PI controllers generate a better output with less rise time and settling time compared to PID controller. However both controller produces a stable output with zero steady state value. Upon investigation on the controller performances from journals, it is found that PI control is more common due to inaccuracies incurred due to offsets in P-only control. Derivative control is less preferable due to the rapid fluctuations in flow dynamics with lots of noise.

As a whole, both cases proves that network induced delay is very prominent in complex fieldbus system. Therefore, considering latency as an important factor in the real time performance is advisable. Fieldbus as a system that provides more advantages than conventional 4-20mA system can be working with higher efficiency with less delay time.

CONCLUSION AND RECCOMENDATION

In conclusion, this project is a study on fieldbus system time delay using SIMULINK. The project is conducted by analysing the performance of customized cascaded model designed by combination of three basic tank models. In general, clients who use fieldbus system obtain their data from internet(fieldbus gateway) or statistical information which is not timing critical. However there are applications where timing is critical such as system notification and alarms where fieldbus system time delay plays an important role. This project has achieved its objective on studying real time control performance and performing delay analysis.

Results that have been obtained from the fieldbus system simulation of combined tank with random variable controller proves that a more complex fieldbus system used in industrial plant has a higher network induced delay and response time. For the case study using a well tuned controller, PI controller generates a better output compared to PID controller. This shows that by performing simulation on the system before hand of implementation in plants, industrial plants can build systems that can meet their specified requirement, with proper tuning and appropriate number of controllers. This can guarantee minimum delay and a stable system which can produce required performance.

Hence for future recommendations, the results obtained from this project can be used in the future for pre-optimization of the sensors before deployment in the plant. Adaptation to this method, can minimize the engineering and hardware cost in plants. Furthermore, the communication network will be able to meet functional requirements, support real time constraints and identify optimal parameters for the better system performance. This can lead into network control system perfection and produce a better solution.

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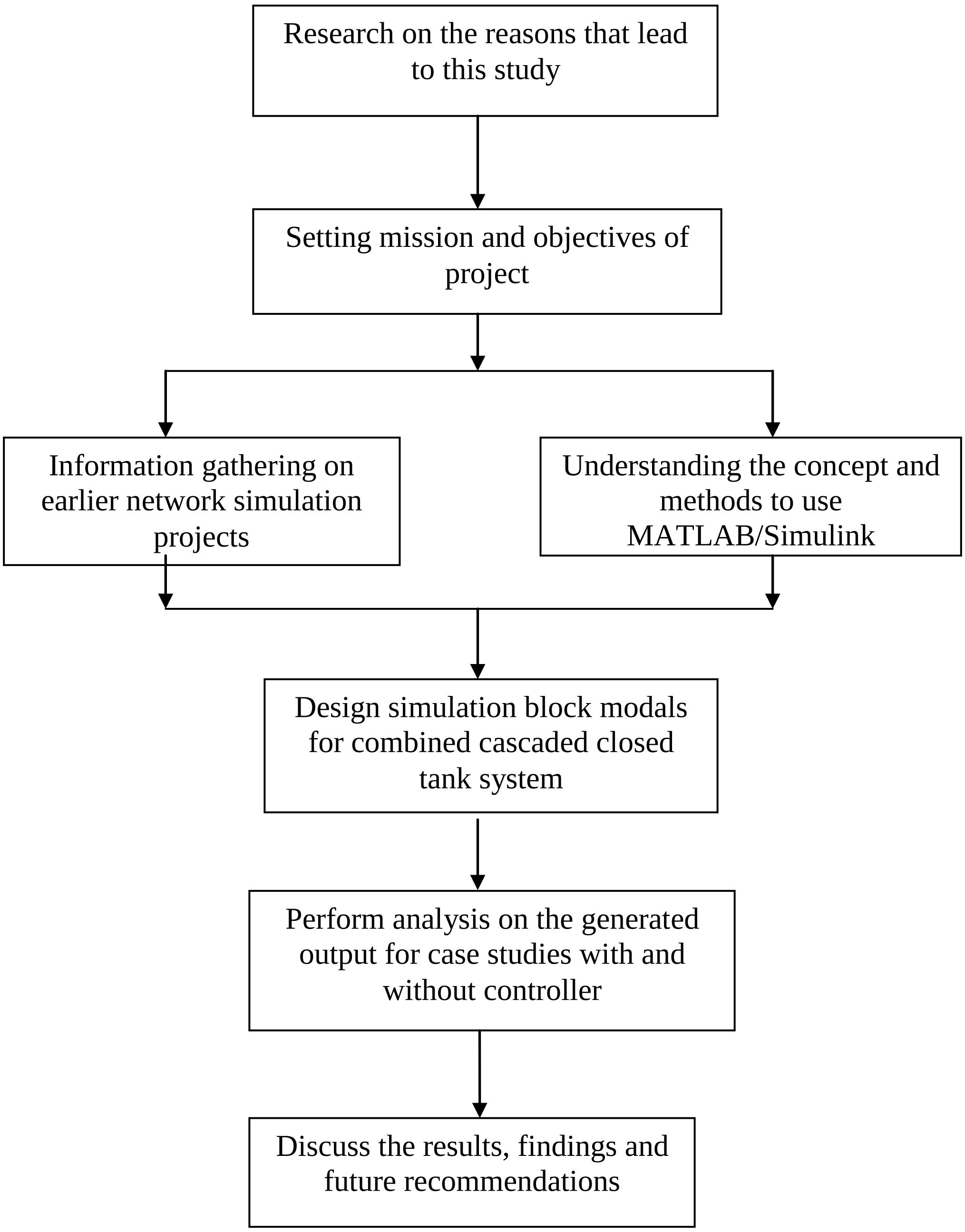
APPENDICES

Appendix 1: Project Flow Chart



Appendix 2: Summary of literature review

Published Year &Author	Description
(ĽUDOVÍT FARKAS, 2012)	The evolution of computer networks, the increase of transfer speed and noise resistance caused the installation of Ethernet technologies in industry more frequent. The most frequently used standard for interconnecting Matlab with industrial devices is the OPC standard. This paper goal was to design a Matlab toolbox for communication with TwinCAT without the use of OPC. [4]
(Ding, Sun, Ye, & Xu, 2010)	To achieve intelligent control algorithm in Foundation Fieldbus process control system, a method which combines LabVIEW and MATLAB to design a real time intelligent control system is presented in this paper. The single neuron PID control algorithm programmed in MATLAB can be stimulated by LabVIEW SIT, the communication between LabVIEW and fieldbus instruments can be established by OPC Server. [1]
(Kyung Chang Lee, JUNE 2004) (L Farkas, 2010)	This paper presents the timer selection method for Profibus token passing net. The communication delay in fieldbus system is affected by performance parameters such as the target rotation timer of token passing protocol. Therefore, it is necessary to select proper parameter settings to satisfy the real-time requirement for communication delay. In order to deliver these data in time, the fieldbus network should be designed to have a short delay compared to the maximum allowable delay. [9]
(L Farkas, 2010)	In this paper it is described on networked control in industrial applications and the possibility to simulate the control systems by True Time. This is because installation of industrial fieldbuses in new industrial applications and plants calls for new approaches to the designing of the control system. The modern networked control systems are usual decentralized systems interconnected by industrial network cables or wirelessly. [10]

(P. Haber, 2003)	This paper is focused on the Rate and Time Continuous Fluid Simulation technology (RTC-FSIM) - a modular and extendable simulation technology based on differential equations paradigm realised in MATLAB and SIMULINK. RTC-FSIM is intended to be used in INTERMON [INTERMON] project for QoS based inter-domain modelling and simulation considering priority classes to describe traffic flows in inter-domain network environment. The RTC-FSIM modelling and simulation approach is compared with the state of the art. Special focus is the explanation of the multi-class signal fluid model and the realisation with MATLAB and SIMULINK. [11]
(Hohwiller & Wendling, 2000)	Fieldbus network simulation requires models of real field devices. The models need to be described in a modelling language and implemented into a simulation environment. In this paper, Estelle has been chosen to specify in a formal language of the PROFIBUS fieldbus protocol. Estelle is used as a general modelling and simulation language for the design of a fieldbus network simulation tool. This paper also presents a modelling methodology which overcomes Estelle shortage in performance evaluation support. The approach is demonstrated on a PROFIBUS-LIP network simulation.[3]
(Hong, 1997)	This paper investigates the effects of network induced delay of fieldbus network on the performance of the distributed control of power systems. Profibus and IECIISA fieldbus are selected as candidate fieldbus protocols for the distributed computer control of power systems. Integrated discrete-event, continuous-time simulation model of fieldbus networks and super-heater temperature-spray control system of power plant is developed for the performance evaluation of network integrated control systems. The simulation model developed in this study can be very effectively utilized in the design, implementation and operation phases of fieldbus network for the distributed computer control of power systems. [12]

Appendix 3: Block Diagram of Combined Tank system