CERTIFICATION OF APPROVAL

Carbon Dioxide Absorption from Natural Gas: Control and Dynamic Study

by

Mohd Ikmal Hisham Bin Azahari

15640

A project dissertation submitted to the

Chemical Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(CHEMICAL ENGINEERING)

Approved by,

____

(Dr Haslinda Bt Zabiri)

UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR, PERAK

September 2015

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 acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

MOHD IKMAL HISHAM BIN AZAHARI

ABSTRACT

A dynamic, non-equilibrium model of Monoethanolamine (MEA) absorption column with operating pressure of about 15 bar was proposed. The MEA solution used in this model to absorb CO_2 from the natural gas. As far as the oil and gas industry had been developing in quite high pace, the method of absorption of CO_2 using MEA is still widely used around the world. For the common fact among people in the oil and gas industry that the high content of CO_2 will cause problems to their operation, thus removing CO_2 from the natural gas itself had become necessary to ensure smooth operation of the oil and gas industry. Aside from that CO_2 gas, other important sour gas exists in the natural gas is H_2S but in this project, the gas that had been study is only CO_2 because this is to make sure the project stay within the timeframe given and also to shrink the scope of study as to get more accurate and precise result in the future. To make the dynamic model successful, model in steady state need to be develop first and in this project, the steady state model was develop using software, Aspen Plus and all the data for completing the simulation had been acquired from the real pilot plant that operate at 15bar and use FLEXIPAC 1Y type of absorber column. The thing that need to be analyze in the dynamic simulation of the MEA absorption model is the effect of changing the lean solvent flow rate and thermodynamic state on the MEA absorption column behavior. Some other variable will also be analyze and studied through the simulation model. Some effective controller had been put in the simulation which is flow controller, temperature controller, pressure controller and level controller. These controller is important to prevent from overflow of the column and to make the process more efficient. The project main concern is that we get some information from the study of previous research paper about MEA absorption column and most of it use operating pressure of 1 bar and all of this will be put in use for the actual absorption column in the future.

ACKNOWLEDGMENT

I would like to acknowledge and extent my full gratitude to the following persons who have made the completion of this Final Year Project possible. First and most important, I would like to extend my gratitude to my respected supervisor, Dr Haslinda Zabiri, who gave me the most support and good guidance towards completing this project. Special thanks to the examiners for the Proposal Defense and Poster Presentation who were being very supportive and guiding me through my mistakes to make the project better and not to forget to my senior for providing good advice and some material to help my project. Last but not least, thanks to my parents, my friends and those who assisted me directly or indirectly in helping and supporting me to complete my project. Thank you very much, may Allah repays your kindness.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Background

Common process of removing acid gas from natural gas were called sweetening process. This process is a very important process involving upstream oil and gas industries. Mostly, it is because the concentration of acid gas in the natural gas can cause corrosion to the pipeline during the transportation of natural gas. Besides, by removing acid gases, gas volume to be transported can be reduced and calorific value of solid gas stream can be increased.

Several process of removing CO_2 (along with H_2S) from natural gas had been developed using the basic action of various amines. Amines can be categorized by the number of organic group bonded to the central nitrogen atom as primary, secondary or tertiary. Primary amines form stronger bases than secondary amines, which form stronger bases than tertiary amines. Most common amines process uses Monoethanolamines (MEA) and Diethanolamines (DEA). Both processes remove CO_2 and H_2S to pipeline specification. However, primary amines had been widely used as gas sweetening agent compared to secondary amines this is because this process is well proven, can meet pipeline specifications and has more design/operating data available than any other system. MEA is a stable compound and in the absence of other chemicals suffer no degradation or decomposition at temperatures up to its normal boiling point. This project study the operation of sweetening process to the natural gas using dynamic modelling and simulation and also to develop a simple decentralized control configuration that maintains the CO2 absorbed and other variable such as temperature, pressure, flowrate and level that needed to be control as to make sure smooth operation of a plants.

1.2 Problem Statement

In most upstream oil and gas industry, CO_2 content in the natural gas is normally high and did not meet the specific requirement by buyer. Thus, the sweetening process of gas is important to make sure the CO_2 content in the natural gas meet the requirement set by the buyer. Apart from meeting the requirements set by the buyer, the important facts about CO_2 content in the natural gas is it can cause corrosion to the pipeline. CO_2 will combine with water to form carbonic acid and this carbonic acid can cause corrosion, reduces heating value and thus sales value. CO_2 usually has to be lower than 2vol% in the sales gas. Most common sweetening process used is amine absorption and the primary amines is the popular one for this process.

Absorption process plants usually come with many problems that may cause the main objective of that plant was not achieve. Some of the problem that can happen inside the plant is the thermal degradation of the MEA and this is cause by high temperature of the reboiler. However, if the temperature of the reboiler is too low, the absorption process efficiency is become low too. This is the main problem that always arises inside an absorption process plant. Another problem that will occur inside the absorption plant is, liquid overflow from the absorber column and common cause of this problem is uncontrolled flow of the liquid solvent. Aside from that, concentration of MEA also play an important roles in the absorption process. This is because high concentration of MEA can cause great effect to the absorption process. Lastly, the operating pressure of the absorption column is also critical factor that can cause large difference in CO_2 absorption rate and to maintain or to control this pressure at optimum condition is one of the problem that may happen.

Some matter that arises is when water makeup increases or decreases and slightly effect the concentration of MEA and also when stripper is relinquished. This is the important factors or problem involving dynamic studies that need to analyze properly. Furthermore, when disturbances variable such as inlet gas flow rate is introduced to the process, what happen or what problem may arises to the process or in dynamic term what change with time. Some of the studies indicate that with increasing of inlet gas flow rate, the reboiler temperature will be affected and in spite of that, the reboiler heat duty also will be affected. That type of scenario is a problem if it cause the process to be not economically. All of this problem will be try to be solve by this studies by focusing on dynamic and control studies using simulation (ASPEN SOFTWARE).

1.3 Objective and Scope of Study

The main objective of this studies is to solve the problem that may arises in the CO_2 absorption process from natural gas by focusing on dynamic and control studies. The objective is to investigate:

1. Important control variable in the absorption plant.
2. Manipulating and disturbances variable that affect the efficiency of the plant.
3. Dynamic behavior in CO_2 capture process.
4. Applying all study that had been made into the pilot plant of Absorption column that run with high pressure, 15 bar.

To complete this study, the scope of study need to be state clearly which is:

1. Simulation of dynamic MEA absorption process model.
2. Type of control and how to manipulate the control variables.
3. Focusing on the dynamic behavior only in CO_2 capture process from natural gas. (This is to make the project feasible within the timeframe and could be completed within the allocated timeframe).

CHAPTER 2
LITERATURE REVIEW

This study show that by using dynamic simulation, the plantwide control of an absorption of CO_2 capture process using monoethanolemines (MEA) was investigated. In this process, operating variable such as lean solvent rate and lean solvent loading will influenced the removal ratio of CO_2, which is in turn determined by reboiler heat duty in the stripper. The long term of stability cannot be achieved unless the water balanced is properly maintained. Hence, the following control structure was proposed. In this scheme, by using the lean solvent feed rate to the top of absorber column, CO_2 removal target is guaranteed. The temperature of the bottom of stripper is controlled by reboiler heat duty in order to operate process with appropriate lean solvent loading. Also, by controlling liquid level in the reboiler stripping column by using water makeup, the overall inventory can be maintained. Optimizing control can be carried out by adjusting the setpoint of reboiler temperature to ensure minimum energy consumption (Lin et al. 2013).

Peters et al (2011) stated that a gas sweetening processes for natural gas with amine absorption process had been analyzed with technical and economic analysis. The process of natural gas sweetening process is a very important issues for many reasons such as corrosion caused by the acid gas concentration in the natural gas. Also, the increases in calorific value of sold gas stream and the removal of acid gases can reduces the gas volume to be transported. To reduces the atmospheric pollution by emission of greenhouse gases as CO_2, the captured acid gases is pumped back in the reservoir. So far, the largest gas separation application worldwide is processing of natural gas. This is because almost all crude natural gas streams require treatment to remove impurities and reduce higher hydrocarbon to meet the pipelines specification. CO_2 usually has to be lower than 2vol% in sale gas, thus it is the requirement that generally makes CO_2 removal necessary.

To predict the dynamic behavior of CO_2 capture process, a dynamic rate-based amine absorption process model has been developed. The proposed mathematical model, comprised of coupled sets of partial differential algebraic equations, includes the nonlinear behavior, and was solved using gPROMS. The model was validate using steady state simulations from Aspen and data available in the literature for this process (Harun et al. 2011).

Bedelbayev et al. (2007) stated that Emission of carbon dioxide and its possible negative effect on the climate has gained much interest lately. Although carbon dioxide has the lowest global warming potential among the greenhouse gases, the emitted amount into the atmosphere is large and continuously increasing. A large amount of the emitted carbon dioxide belongs to the energy sector (power plant etc) where the fossil fuel and natural gas are use. The capturing of carbon dioxide to reduce its release into the atmosphere is thus of great interest. Several methods exists to capture carbon dioxide, e.g. the post-combustion, pre-combustion, and oxyfuel methods.

With an increasing demand on load flexibility in power supply networks. Advanced control systems for plants with carbon capture units gain in significance. Minimizing the energy demand for carbon dioxide removal under these circumstances is a major task of such a control strategy. In this work a dynamic model in Modelica of a chemical absorption process run with an aqueous monoethanolamine (MEA) is developed. Starting from a rather detailed dynamic model of the process, model reduction is performed based on physical insight. The reduced model computes distinctly faster, shows similar transient behavior and reflects trends for optimal steady-state operations reported in the literature. The model is intended to be used in the framework of JModelica.org, a platform supporting non-linear dynamic optimization (Prolb et al. 2011).

CHAPTER 3
METHODOLOGY OF THE PROJECT

3.1 Project Flow Chart

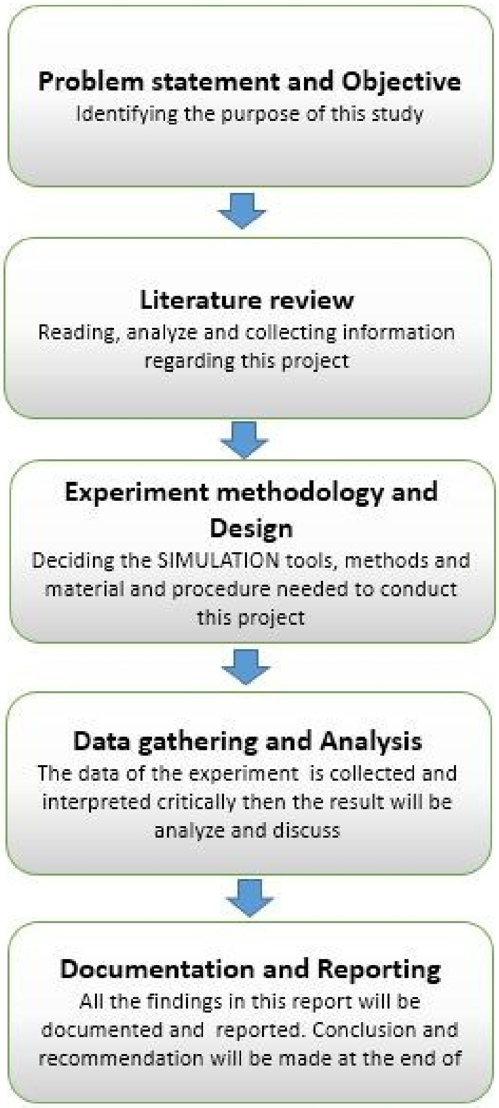

Figure 3.1 Project Flowchart

Table 3.1 Gantt Chart and Key Milestone 1

FYP 1

No	Details	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topics														
2	Literature Review and Theory Findings														
3	Submission of Extended Proposal to Supervisor														
4	Proposal Defense														
5	Model Simulation and Conduct Studies based on Simulation														
6	Submission of Interim Draft Report														
7	Submission of Interim Final Report														
8	Submission of Marks by Supervisor														

	Progress
	Milestone

Table 3.2 Gantt Chart and Key Milestone 2

FYP 2

No	Details	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Result and Discussion														
2	Submission of Progress Report														
3	Conclusion and Recommendation														
4	Pre-SEDEX														
5	Submission of Draft Final Report														
6	Submission of Dissertation (Soft Bound)														
7	Submission of Technical Paper														
8	Viva														
9	Submission of Project Dissertation (Hard Bound)														

	Progress
	Milestone

3.3 Simulation of Steady State model using Aspen Plus

NG flow rate (slpm)	CO2 flow rate (slpm)	Total gas inlet (g/min)	Liquid flow rate (kg/min)	CO2 (%)	CH4 (%)	LT 01 (%)	PT 03 (barG)
50.23	49.2	103.13	0.93	48.75	52.78	1.85	10.62

Figure 3.2 Feed Data

Structured packing	20wt% MEA, 0.85 l/min		
T solvent = ~40deg C			
Condition of pcked column : Flexipac 1Y, diameter is 145 mm, height is 1 meter			
MEA			

Figure 3.3 Column Data

The first step to make the model is to acquire the data from the figure 3.2 for the feed stream and also the data from figure 3.3 for the absorber column. The data for the absorber column and feed data had been acquired from the pilot plant with operating pressure of 15 bar in Universiti Teknologi PETRONAS (UTP).

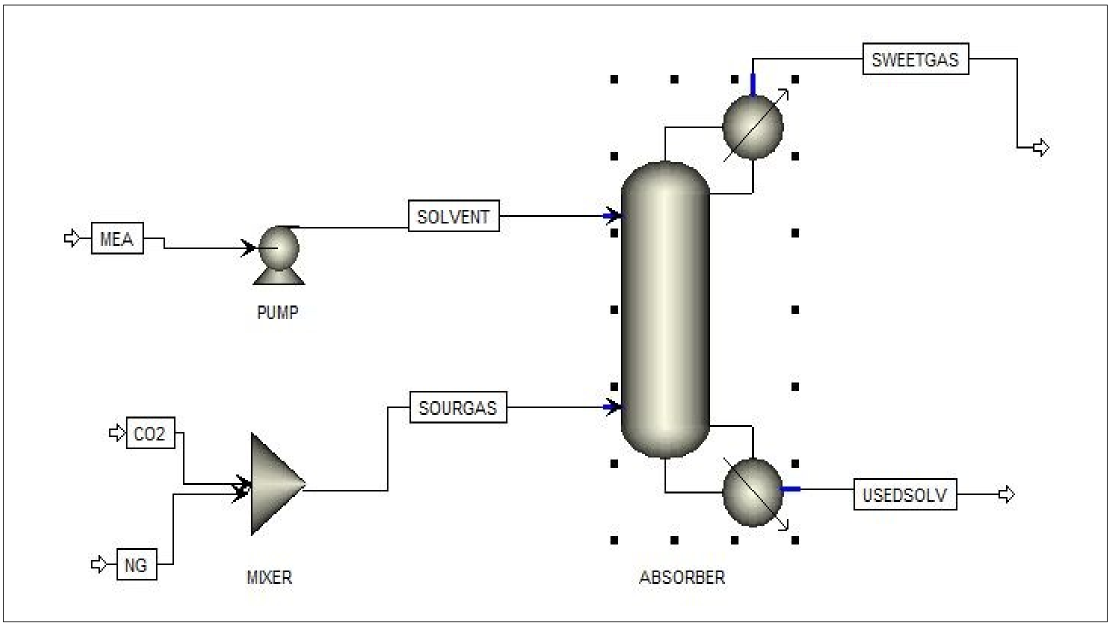

Figure 3.4 Simulation of Steady State

From the figure 3.2, the feed data acquired has about 50% of Methane composition and also about 50% composition of CO_2.

To make this simulation of steady state successful, some assumption need to be made. The composition of CO_2 in the natural gas stream is assume to be about 0.03 mole fraction for the composition and the remaining composition of the natural gas stream is Methane, 0.97 mole fraction.

The flow rate for the natural gas stream is about 50.24 slpm and the flow rate for the carbon dioxide stream is about 49.2 slpm and the total inlet will be 103.3 g/min. The liquid Monoethanolamine (MEA) flow rate is 0.93 kg/min.

The absorption column used is FLEXIPAC 1Y with diameter of 145mm and height about 1m, the packed structure inside the column consist of three part and the total height of all the three is about 1m.

The figure 3.4 shows the steady state simulation of MEA absorption column using Aspen Plus software.

3.4 FLEXIPAC 1Y COLUMN

FLEXIPAC structured packing provides a lower pressure drop per theoretical stage and increased capacity compared to trays and conventional random packings. Available in multiple materials from traditional stainless steel to high alloys, modern duplex steel and exotic materials such as titanium and zirconium for customers to acquire.

FLEXIPAC structured packing is available in two configurations: Y and X, and the one in the UTP is Y configuration. The 'Y' designated packings have a nominal inclination angle of 45^0. They are the most widely used in new installations. While the 'X' packings have a nominal inclination angle of 60^0 from horizontal and are used where high capacity and low pressure drop are the foremost requirements for a specific application. The 'X' packings provide a lower pressure drop per theoretical stage compared to the same size 'Y' packing.

Efficiency FLEXIPAC® Structured Packing	
Size	HETP*
700Y	6.3 in [160 mm]
500Y	9.1 in [230 mm]
1Y	8.3 in [210 mm]
350Y	8.9 in [225 mm]
1.6Y	10.0 in [255 mm]
250Y	12.4 in [315 mm]
2Y	13.8 in [350 mm]
2.5Y	22.4 in [570 mm]
3Y	31.5 in [800 mm]
3.5Y	43.3 in [1100 mm]
4Y	62.6 in [1590 mm]

Efficiency FLEXIPAC® Structured Packing	
Size	HETP*
1X	13.4 in [340 mm]
350X	14.2 in [360 mm]
1.6X	16.9 in [430 mm]
250X	20.1 in [510 mm]
2X	22.4 in [570 mm]
2.5X	32.3 in [820 mm]
3X	45.3 in [1150 mm]
3.5X	61.9 in [1570 mm]
4X	89.4 in [2270 mm]

* HETP values are estimates based on atmospheric distillation systems with low relative volatility and good liquid/vapor distribution. Contact Koch-Glitsch for non-ideal systems.

Figure 3.5 Flexipac Column Data

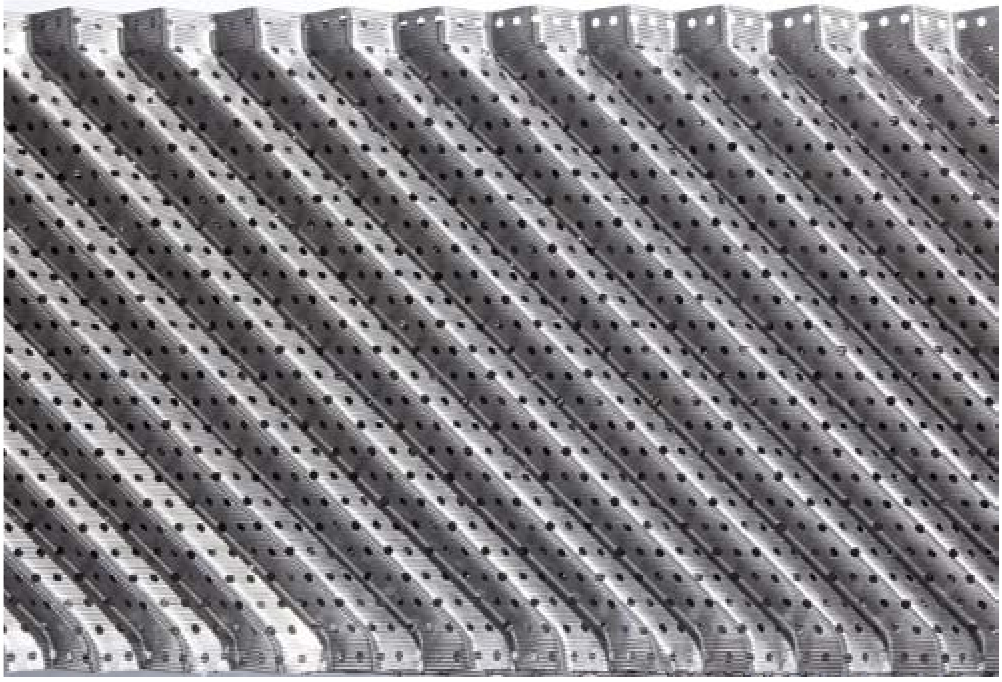

Figure 3.6 Flexipac Column Sample

The pilot plant in UTP use FLEXIPAC 1Y, thus it will have HETP of about 8.3 inch. This data will be needed in other to fully complete the dynamic simulation of the MEA absorption column later.

From the figure 3.5 and 3.6, it can be shown that, it is the structured packings in the column tower and it consists of three part or compartment with that structure. That is the structure needed in other to fully enhance the process of absorption of CO_2 into MEA solvent.

3.5 Result for Steady State Simulation Model

Table 3.3 Steady State Result Data

Substream	CO_2	MEA	NG	SOLVENT	SOURGAS	SWEETGAS	USEDSOLV
CH4	0	0	0.1819593	0	0.1819593	0.1497265	0.0322328
CO_2	0.0664624	0	5.63E-03	0	0.07209	0.0175447	0.0545453
H2O	0	1.51283	0	1.51283	0	8.42E-04	1.511988
MEA	0	0.3782075	0	0.3782075	0	2.60E-06	0.3782049
Total Flow kmol/hr	0.0664624	1.891037	0.187587	1.891037	0.2540494	0.1681162	1.976971
Total Flow kg/hr	2.925	50.35638	3.1668	50.35638	6.0918	3.1895	53.25868
Total Flow l/min	2.782756	0.85	7.854187	0.8508501	9.758663	6.647204	0.9076552
Temperature C	29	40	29	40.97405	29	40.71736	39.67064
Pressure bar	10	1	10	11	10.9	11	11
Vapor Frac	1	0	1	0	1	1	0
Liquid Frac	0	1	0	1	0	0	1
Solid Frac	0	0	0	0	0	0	0
Enthalpy cal/mol	-93952.57	-67457.78	-20050.28	-67435.99	-39384.03	-25814.99	-67370.53
Enthalpy cal/gm	-2134.81	-2533.248	-1187.688	-2532.43	-1642.452	-1360.689	-2500.805
Enthalpy cal/sec	-1734.533	-35434.77	-1044.769	-35423.33	-2779.303	-1205.533	-36997.1
Entropy cal/mol-K	-3.73862	-53.2703	-22.81699	-53.20075	-17.01006	-20.69294	-51.24145
Entropy cal/gm-K	-0.0849497	-2.000464	-1.351575	-1.997853	-0.7093791	-1.09071	-1.902091
Density mol/cc	3.98E-04	0.0370791	3.98E-04	0.0370421	4.34E-04	4.22E-04	0.0363017
Density gm/cc	0.0175186	0.9873799	6.72E-03	0.9863934	0.0104044	8.00E-03	0.9779535
Average MW	44.0098	26.62897	16.88177	26.62897	23.9788	18.972	26.93954
Liq Vol 60F l/min	0.0593263	0.8334186	0.1674457	0.8334186	0.2267721	0.1495673	0.9106235

After completing the steady state simulation model, the model had been run and the result had been obtain as the table 3.3.

From the table 3.3, it can be seen that the composition of CO_2 in the sweet gas stream had been decrease to about 0.017 means 1.7% of composition of CO_2 exists in the sweet gas. This amount of composition of CO_2 is acceptable as usually buyer of natural gas, most of them wants their natural gas have the composition of CO_2 less than 2% to ensure and to control their quality of natural gas.

Most of the CO_2 that originally exists in the natural gas had been absorb by MEA solvent and there from the table 3.3 it can be shown that the content of CO_2 from the MEA stream increase from 0 to 0.05 in the used solvent stream. This proved that the MEA successfully absorb the CO_2 that exists originally in the natural gas. However this is just only the steady state model of the absorption column, a dynamic simulation model will be develop next to make the study and investigation more precise and accurate as in the real situation of the industry, as most of the process is not in steady state.

3.6 Entering Dynamic Simulation

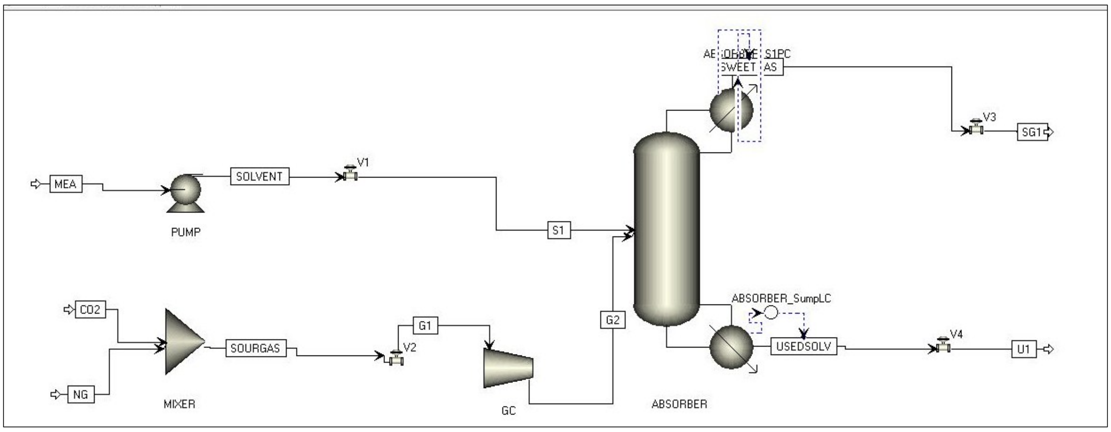

Figure 3.7 Simulation of Dynamic State

Before entering dynamic state from steady state, several steps need to be taken to properly entering Aspen Dynamic from Aspen Plus.

Assumption need to make in other to enter dynamic environment:

1. Major component of the liquid stream is inert and does not absorb into the gas.
2. Major component of the gas stream is inert and does not absorb into the liquid stream.
3. Each stage is in equilibrium stage, the vapor leaving a stage is in the thermodynamic equilibrium with the liquid on the stage.

The absorber column need to be sizing and rating, the packing geometry need to be properly stated in the simulation.

Then, it is in good practice to add control valve before entering dynamic state in Aspen plus.

After all steps had been taken, then the dynamic simulation can be enter from the steady state.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Dynamic Behavior: MEA Liquid Stream

4.1.1 MEA Liquid Flow rate

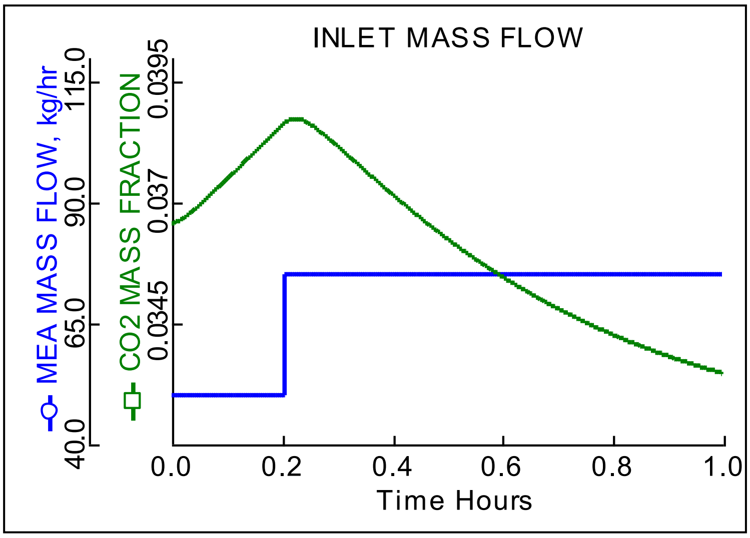

Figure 4.1 Dynamic Behavior of MEA Inlet Mass Flowrate

Figure 4.1 shows the dynamic behavior of the MEA absorption process when the MEA inlet solvent had been varied. The experiment performed was varying the effect of increasing the flowrate of the MEA inlet solvent. It was observed that when the mass flowrate of MEA inlet solvent is being increased from 50 kg/hr to about 75 kg/hr at time of 0.2 hours, the mass fraction of CO_2 in the used solvent stream had been decreased. The possible reasons for this is because when the mass flowrate of MEA increased, the concentration of MEA also had been affected, as the concentration of MEA in the inlet stream is already low enough, thus when the flowrate had been increased, the effect of the absorption process also decreased. Then, to get the best efficiency for this process, make sure that the concentration of MEA is sufficient when the mass flowrate is being increase.

4.1.2 MEA Liquid Temperature

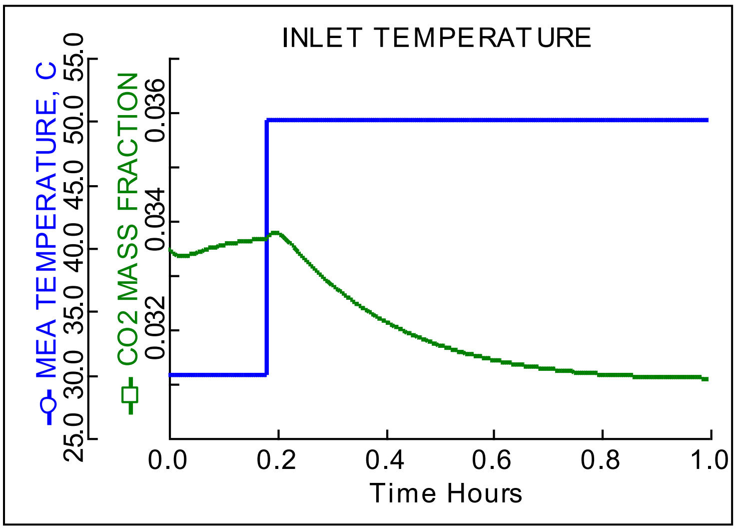

Figure 4.2 Dynamic Behavior of MEA Inlet Temperature

From the figure 4.2, the temperature of the inlet solvent stream had been increased from 30°C to about 50°C. When the temperature had been increased, the dynamic behavior for the process can be seen where the mass fraction of CO_2 absorbed in the used solvent also start decreasing. This shown that by increasing the temperature of the MEA inlet solvent, the efficiency for the absorption process will be decreased. The main reasons for this is because when the temperature of the MEA solvent increased, MEA will start to degrade, thus decreasing the efficiency of the process. However, it is important to know that MEA also function better at temperature range from 30°C to 40°C.

4.1.3 MEA Liquid Composition

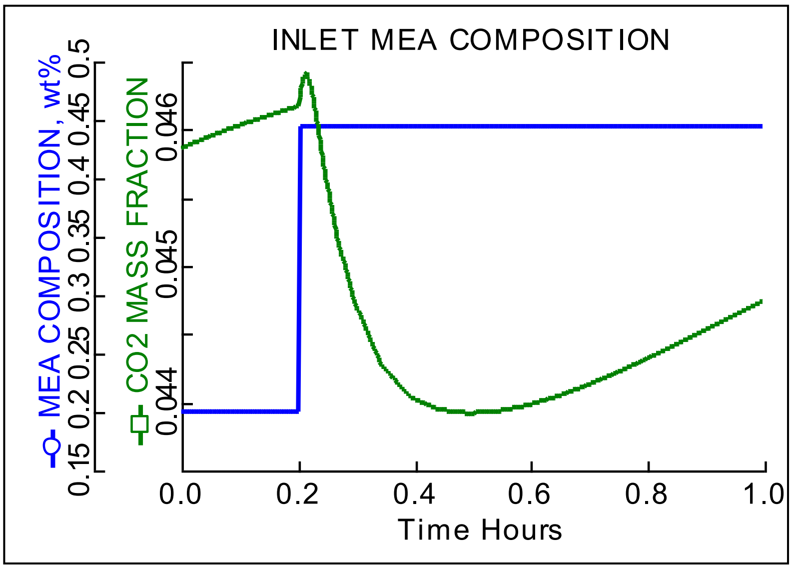

Figure 4.3 Dynamic behavior MEA Inlet Solvent MEA Composition

The composition of MEA is being manipulated in the MEA solvent stream by varying the mole fraction at certain time from 0.2 to 0.4 mass fraction, it can be shown in the figure 4.3 that the mass fraction of the CO_2 absorbed in the solvent had been slightly decreased before increasing back when the composition of MEA increased from about 0.2wt% to about 0.45wt%. The reasons for the slightly decrease is because of sudden increase of the MEA composition in the inlet solvent, the simulation need to stabilize the process back, however the true dynamic behavior can be seen at time 0.4 hours when the mass fraction of CO_2 is increasing. The efficiency of this process depended on the amount of composition of MEA in the inlet solvent, while the efficiency will be increased when the composition also increased.

4.2 Control Structure

4.2.1 Flow Controller

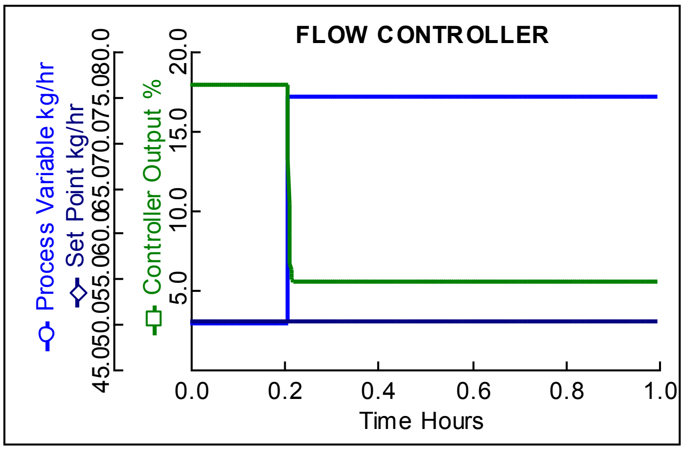

Figure 4.4 Flow Controller

From the figure 4.4, the function of the controller is being investigated by introducing the step disturbance into the system. For this case, the sudden increasing of the mass flowrate from 50kg/hr to 75kg/hr had been used as the step disturbance. From the figure 10, it can be seen that when the mass flowrate is increasing, the controller do their role by decreasing (green line) the opening of the valve after the stream, this is to to maintain the flow at 50kg/hr at all time. The main reason for maintaining the flowrate is to prevent disturbance to the process as the efficiency of the process will be affected and problem may arises so, it better to fix the flowrate at certain value for the ease of operation.

4.2.2 Temperature Controller

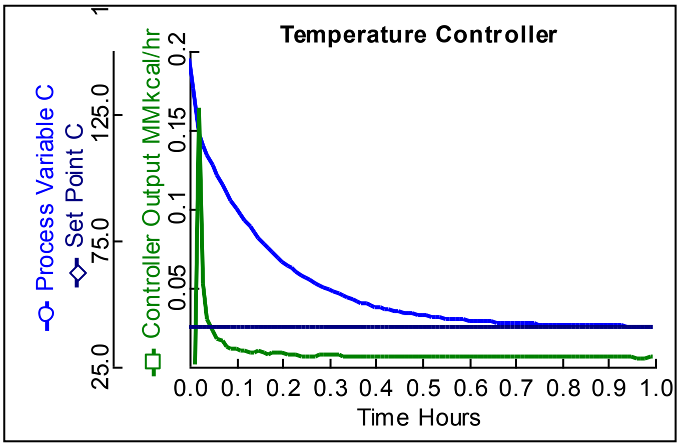

Figure 4.5 Temperature Controller

From the figure 4.5 the function of the controller is being investigated by introducing the step disturbance into the system. For this case, the sudden increasing of the mass flowrate from 50kg/hr to 75kg/hr had been used as the step disturbance. From the figure 11, it can be seen that when the temperature increased due to increase in mass flowrate, the temperature of the column also increased, then the controller will decrease (green line) the value of reboiler duty in the column as to maintain the temperature of the column. The main reason to maintain the temperature of the column is to prevent the MEA solvent degrade due to high temperature thus disturbing the efficiency of the overall processed.

4.2.3 Level Controller

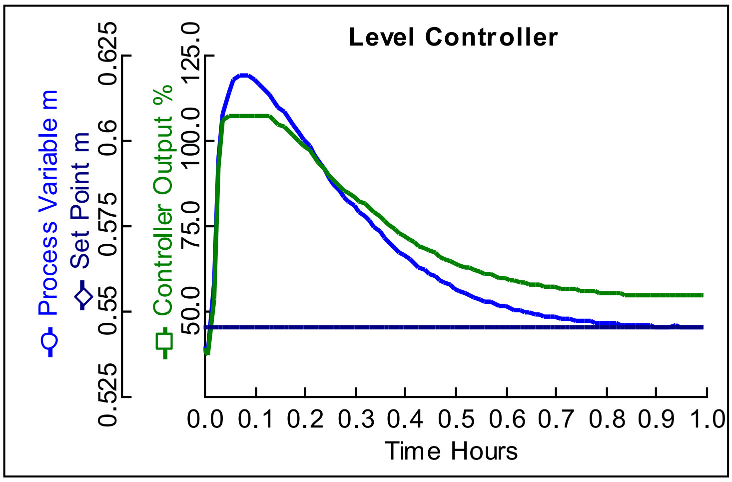

Figure 4.6 Level Controller

From the figure 4.6 the function of the controller is being investigated by introducing the step disturbance into the system. For this case, the sudden increasing of the mass flowrate from 50kg/hr to 75kg/hr had been used as the step disturbance. From the figure 11, it can be seen that when the level increased due to increase in mass flowrate, the controller will increase (green line) the opening of the valve at the bottom product of the column so that the excess liquid will exit more and the level inside the column will be maintain. This type of controller is important because with this level controller, spillage from the column or backflow can be prevent thus the efficiency and safety of the process will increase.

4.2.4 Pressure Controller

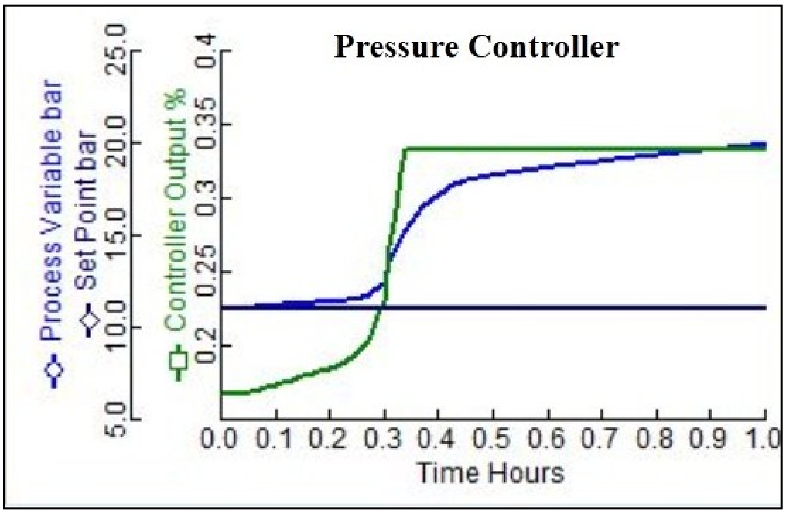

Figure 4.7 Pressure Controller

From the figure 4.7 the function of the controller is being investigated by introducing the step disturbance into the system. For this case, the sudden increasing of the mass flowrate from 50kg/hr to 75kg/hr had been used as the step disturbance. From the figure 11, it can be seen that when the level increased due to increase in mass flowrate, the controller will increase (green line) the opening of the valve at the top product of the column so that the excess gas will exit more and the pressure inside the column will be maintain. This type of controller is important because with this pressure controller, fix pressure of the system can be maintain thus maintaining the quality of the product.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

As conclusion, this study had been carried out to determine how dynamic behavior occur in the CO_2 absorption from natural gas and also to find the correct type of control uses in the absorption process in order to optimize the system. The step disturbance that had been introduced to the system when doing the dynamic behavior study had caused some change in the absorption process, thus several controller had been installed in other to maintain the efficiency of the process. Furthermore, this project can be consider feasible to the time frame because students are in final year and already undergo experience in real industry and in spite of that, students also will receive minimal guidance from supervisor that is already expert in this project category.

For recommendation, any study that involve the use of simulation software need to be conduct properly and also strong basic understanding about the software in use will be needed. So, it is highly recommended that students need to properly learn the software before starting any of the project.

REFERENCES

Freguia, S., & Rochelle, G. T. (2003). Modeling of CO_2 capture by aqueous monoethanolamine. Aiche J 2003, 49 (7). 1676-1686.

Harun, N., Douglas, P. L., Croiset, E., & Sandoval, L. A. (2013). Dynamic Simulation and Control of MEA Absorption Process for CO_2 Capture from Power Plants. *Proceedings of the 6th International conference on Process Systems Engineering (PSE ASIA) 25 -27 JUNE 2013, Kuala Lumpur.*

Kvamsdal, H., M., Jakobsen, J. P., & Hoff, K. A. (2009). Dynamic modeling and simulation of a CO_2 absorber column for post-combustion CO_2 capture. *Chem Eng Process* 2009, *48* (1). 135-144.

Lawal, A., Wang, M., Stephenson, P., & Yeung, H. (2009). Dynamic modelling and simulation of CO_2 absorption for post combustion capture in coal-fired power plants. *Fuel,* 88(12). 24-62.

Lawal, A., Wang, M., Stephenson, P., & Yeung, H. (2009). Dynamic modelling and simulation of CO_2 absorption for post combustion capture in coal-fired power plants. *10th International Symposium on Process Systems Engineering – PSE 09 Brazil.*

Lin, Y., Pan, T., Wong, D., & Jang, S. (2011). Plantwide Control of CO_2 Capture by Absorption and Stripping Using Monoethanolamine Solution. *American Control Conference on O'Farrell Street, San Francisco, CA, USA, JULY 2011.*

Peters, A., Hussain, A., Follmann, M., Melin, T., & Hagg, M. (2011). CO_2 removal from natural gas by employing amine absorption and membrane technology – A technical and economical analysis. *Chemical Engineering Journal 172 (2011)*. 952-960.

Simon, L. L.; Elias, Y., Puxty, G., Artanto, Y., & Hungerbuhler, K. (2003) Rate based modeling and validation of a carbon-dioxide pilot plant absorbtion column operating on monoethanolamine. *Chemical Engineering Research and Design In Press, Corrected Proof*.

Yang, H., Xu, Z., Fan, M., Gupta, R., Slimane, R. B., Bland, A. E., & Wright, I. (2008). Progress in carbon dioxide separation and capture. *a review, J. Environ. Sci. 20 (2008).* 14–27.

Ziaii, S., Rochelle, G. T., & Edgar, T. F., Dynamic Modeling to Minimize Energy Use for CO_2 Capture in Power Plants by Aqueous Monoethanolamine. *Ind Eng Chem Res* 2009, *48* (13). 6105-6111.