CHAPTER 1

INTRODUCTION

In chemical industry, the knowledge of dynamic behavior of the system is very important in many activities such as: equipment design, process control system design, process optimization planning, selecting the operating condition, and implement an automation technique. The need for understanding dynamics is first illustrated through the discussion of this simple example. The example involves the dynamic response of a bus and a bicycle. When a driver wishes to maneuver the vehicle, such as to make a 180° U turn, a bicycle can be easily turn in a small radius, while a bus requires an arc of considerably larger radius. Clearly, the design of the vehicle affects the possible maneuverability, even when a bus has an expert driver. Also, the driver of a bus and the rider of a bicycle must use different rules in steering. This simple example demonstrates that (1) a key aspect of automation is designing and building equipment that can be easily controlled, and (2) the design and implementation of an automation system requires knowledge of the dynamic behavior of the system

As discussed above, in chemical processes, for example, an acetylene hydrogenation process that is a more complex system, the dynamic behavior of process can not be studied only through theories or books. The other alternative ways that can improve the process knowledge are an experimental approach, a pilot plant, and a process simulation. An experimental approach and a pilot plant need high cost and long time more than a process simulation. Thus, the dynamic simulation is continuously developed and used as the tool for improved the process knowledge. Moreover, the dynamic process model is developed that can be helpful in an other ways:

- It can be used as the basic for classical controller design method.

- It can be incorporated directly in the control law, an approach that now is the starting point for many advanced control techniques.
- It can be used to develop a computer simulation of the process to allow exploration of alternative control strategies and to calculate preliminary values of controller setting.
- It can be used to study for an optimization problem.

Due to, the process behavior can be find out through the simulation model, thus, if can develop the mathematical model that can exactly obtain the real process, the best knowledge of dynamic behavior of process and the best control for the process will discover.

This thesis focuses on the area of process modeling of an acetylene hydrogenation process because of the problem of ethylene loss in an industrial plant. The industrial plant has the problem of ethylene loss from the acetylene removal unit (acetylene hydrogenation process). The production planning of the industrial plant is to minimize the ethylene loss from the acetylene hydrogenation process. An important tool for the optimization is the simulation model, thus, this thesis develops the acetylene hydrogenation process model to improve the process knowledge and to use as the tool for optimization.

For this thesis, The presentation of the task can be separated into three parts. The first is the part of the process modeling for an acetylene hydrogenation process. The studies will be carried out on a mathematical model derived from fundamental equations and checked against with industrial data. However, the industrial data that used to develop the model is inaccurate. The data must be proceeded for more accuracy before used to develop the model. Thus, the second part, the area of data reconciliation is concerned. The last part presents the structure of the dynamic matrix control algorithm that is designed by using the process model and the benefit of the developed controller.

1.1 Acetylene hydrogenation process

Acetylene hydrogenation process or acetylene-removal system is a process of considerable importance in the manufacture of polymer-grade ethylene. Acetylene is one of the minor product produced in the cracking furnaces as a by-product of high temperature pyrolysis reactions that also produce ethylene and propylene. Production of on specification ethylene product requires removal of almost all the acetylene in cracked gas because acetylene is an undesirable impurity in polymer-grade ethylene.

The processes for the removal of acetylene in industrial plant can be divided into four types:

1. Solvent absorption.
2. Cracked gas train hydrogenation reactor.
3. Tail-end catalytic reactor: hydrogenation of the C2 fraction of the cracked gas.
4. Front-end selective catalytic reactor: hydrogenation of the C2 or C3 and lighter portion of the cracked gas.

These four process types evolved in the same order as listed. The first three processes can be found in ethylene plants using the conventional front-end demethanizer process sequence. The front-end selective catalytic hydrogenation reactor can be found in plants using a front-end deethanizer or front-end depropanizer process sequence.

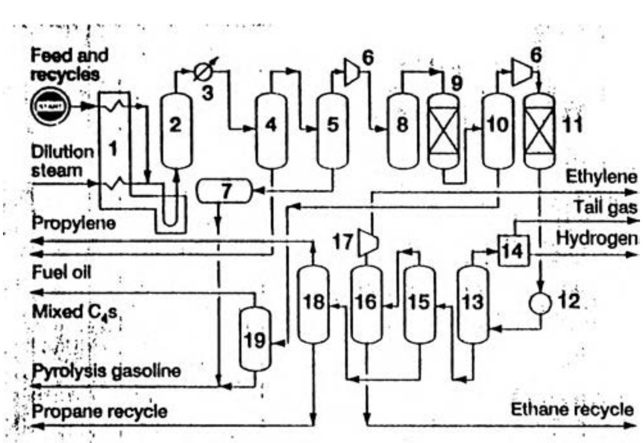

Figure 1.1 The ethylene plant with the front-end selective catalytic reactors

Front-end selective catalytic reactors, the converters are located prior to the cold train of the ethylene plant. In other words they are located after the cracking section, following a caustic scrubbing treatment to eliminate CO_2. This means that only the inlet temperatures are available as control variables as the cracked gas already contains significant quantities of hydrogen. This option, known as front-end catalytic hydrogenation reactor, is the subject of this task.

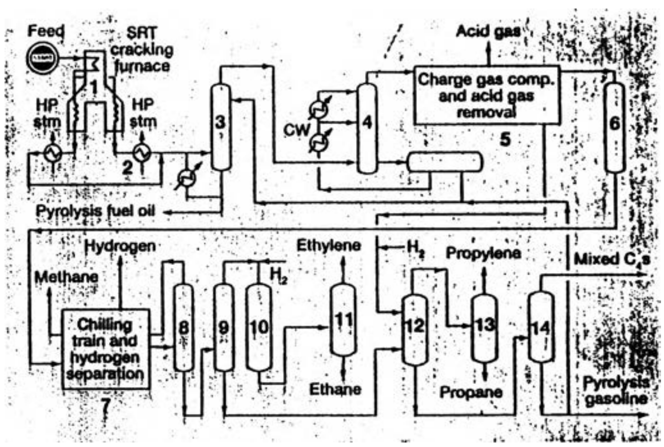

Figure 1.2 The ethylene plant with the tail-end catalytic reactors

Tail-end catalytic reactor, the converters are located after the cold-train where hydrogen is removed from the cracked gas. That is the converters hydrogenates the ethylene-rich stream arising from the top of the deethanizer column. Hydrogen must be injected into the feed to the converters and the hydrogen concentration is available as a control variable, in addition to the inlet temperatures to the reactor beds.

1.2 Dynamic simulation using SPEEDUP

An acetylene hydrogenation process model is developed from the process flow diagram and process design data of the real plant. The set of mathematical equations such as: material and energy balance equations, thermodynamic equations, and reaction rate equations are written on the SPEEDUP program to develop the model for an acetylene hydrogenation process. The SPEEDUP is a modeling and simulation development program or specific language that is designed to model processes as they occur in chemical or process engineering environments (as a series of unit operations interconnect by process streams). The programmer can easily write mathematical models of complex processes in a designed high level language, and requires minimal user documentation for study. The SPEEDUP program is very helpful in many application of engineering such as: optimization, parameter estimation, and data reconciliation because the SPEEDUP can be easily simulated with four types of simulation running mode(steady state, dynamic, estimation, and optimization modes) and can be linked with the external software. All running modes are steady state run, dynamic run, estimation run and optimization run. Thus, it is very comfortable to develop the process model by SPEEDUP because you can simulate the model in several modes by using the same main section of model.

1.3 Data reconciliation

The measurement systems in every industrial plants usually have an inaccurate data problem but many activities in chemical industry (such as: operation planning schedule, project planning schedule, consideration of process performance, consideration of process control performance, parameters estimate for model equations, and etc.) need an accurate data. Therefore, an approach named data reconciliation is needed in order to reduce the error of the measurement data and makes the data to satisfy the material and energy balance. Data reconciliation is an approach that base on material and energy balance laws and can be typed into an optimization problem because the data reconciliation objective function is a minimize sum of square error between the measured values and the adjust values equation.

1.4 Dynamic Matrix Control

Main objectives of an industrial production are the excellent product quality, the desired rate of production, and the lowest cost of production. To get the best of all objective as described above, the control system has become increasingly important and has been developed continuously. One control algorithm that proper with a high nonlinear system is the Dynamic Matrix Control (DMC). The Dynamic Matrix Control is the model-based control approach that utilized a process model to predict the future values of the process output and to optimize a quadratic objective function involving the error between a set point and a predict output.

1.5 Objective of the thesis

This thesis focuses on process modeling, the dynamic data reconciliation and control of an acetylene hydrogenation process with the following purpose:

1.5.1 Develop the mathematical model for the catalytic fixed-bed acetylene hydrogenation process.

1.5.2 Develop the dynamic data reconciliation program for the catalytic fixed-bed acetylene hydrogenation process.

1.5.3 Develop a Dynamic Matrix Control program for the reactors.

1.6 Scope of the thesis

1.6.1 Develop the simulation model for the front-end selective catalytic fixed-bed acetylene hydrogenation system consisting of:

1. Three catalytic fixed-bed acetylene hydrogenation reactors using the palladium catalyst supported on an alumina.
2. Preheated system and two inter-cooler systems.

1.6.2 The data reconciliation algorithm is the weight least square equation like an objective function, for the created model.

1.6.3 The dynamic matrix control algorithm is developed by Cutler and Ramaker(1980).

1.6.4 All programs are written by using the SPEEDUP software.

1.7 Structure of the thesis

This thesis contains three main subjects that are composed with nine chapters. Chapter 1 presents the overview of the thesis. The objectives and scopes of the thesis are also presented in this chapter. Part 1 of thesis covers in the theories of process modeling and the case study in an acetylene hydrogenation process of the industrial plant. The concept of process modeling and theories are presented in chapter 2. The reviews and details of an acetylene hydrogenation process are presented in chapter 5 The modeling of an acetylene hydrogenation process, the developed model, and simulation results are presented in chapter 6.

Part 2 covers in the theories and computational basis for data reconciliation approach that are presented in chapter 3. The application of data reconciliation that is applied for an acetylene hydrogenation process and the simulation results is presented in chapter 7.

Part 3 covers in the Dynamic Matrix Control subject. The theory is presented in chapter 4. The controller design for an acetylene hydrogenation process and the performance of controller are presented in chapter 8. The last chapter, chapter 9 is the discussion and conclusion chapter. Moreover, the other important subjects such as the mathematical background theories, the simulation results of other developed models, and SPEEDUP background are presented in the area of appendix A, appendix B, and appendix C in sequence.