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Title

Simulation of a Deethanizer in Aspen Hysys: A PID Integration Study

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Dedication

This thesis is dedicated to the people who have supported me consistently along this journey.

To my dear mother, who has always been my source of strength and guidance with her constant love, prayers, and support. Your unending generosity and faith have always motivated me to pursue greatness.

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List of abbreviation

JGC: Japan Gasoline Corporation

LPG 2: Liquified petroleum gas 2 facility

LPG: Liquified petroleum gas

PID: Proportional-Integral-Derivative

PLC: programmable logic controller

HMI: Human-Machine Interface

DCS: Distributed control systems

P&IDs: Piping and instrumentations diagrams

PV: process variable

SP: Set point

General Introduction

General introduction

Process control is an interdisciplinary field combining statistics and engineering, focused on developing mechanisms, architectures, and algorithms to regulate various processes. its function has changed throughout time as a result of ongoing technical developments. in industrial operations it has historically been concerned with maintaining variables close to desired values in order to optimize processes, ensure safety, and minimize environmental effect. A process engineer is usually involved in any operation that needs to be continuously monitored. In the past, operators and engineers at the unit level kept an eye on these processes locally. [1]

For more than seven decades, the foundation of control engineering practice has been composed on proportional integral (PI) and proportional integral derivative (PID) controllers. Still, until the last 20 years, the PID controller has not attracted much attention from the academic research community. Work by K.J. Åström, T. Hägglund, and F.G. Shinskey, among others, has reignited interest in using the controller. [2]

The objective of this dissertation is to study the integration of a PID controller within Aspen HYSYS by simulating the deethanizer 11-C-201, operating in the LPG 2 facility in Hassi Massoud, and then implementing the controller in the simulated environment.

The paper’s chapters are titled as follows:

- Chapter I : LPG 2 facility.
- Chapter II : Instrumentation and control engineering.
- Chapter III : Steady state simulation.
- Chapter IV : Dynamic state simulation.

Chapter I
LPG 2
Facility

Introduction

In this chapter, we will discuss the science and process of the LPG 2 gas treating facility. We will highlight the operational aspects and the equipment involved in the facility.

This work is based on a comprehensive two-week internship conducted at the LPG 2 facility from May 18th to May 31st 2024.

1. LPG

1.1 Definition:

Liquid Petroleum Gas (LPG), a mixture of butane, propane, and other light hydrocarbons. Compared natural gas and hydrogen, LPG can be easily stored and transported due to lower liquefaction pressure range of 0.7 to 0.8 MPa at standard room temperature [3].

LPG is sourced from petroleum or natural gas and is almost entirely derived from fossil fuels. It is obtained during the petroleum refining process or extracted from natural gas streams as they come from the ground. [3]

Figure 1.1 LPG storage spheres [4]

1.2 Utilization

The applications of LPG in the petrochemical or chemical industries are [5]:

- Fuel for electricity generation.
- Heating source for industrial furnaces and feedstock.

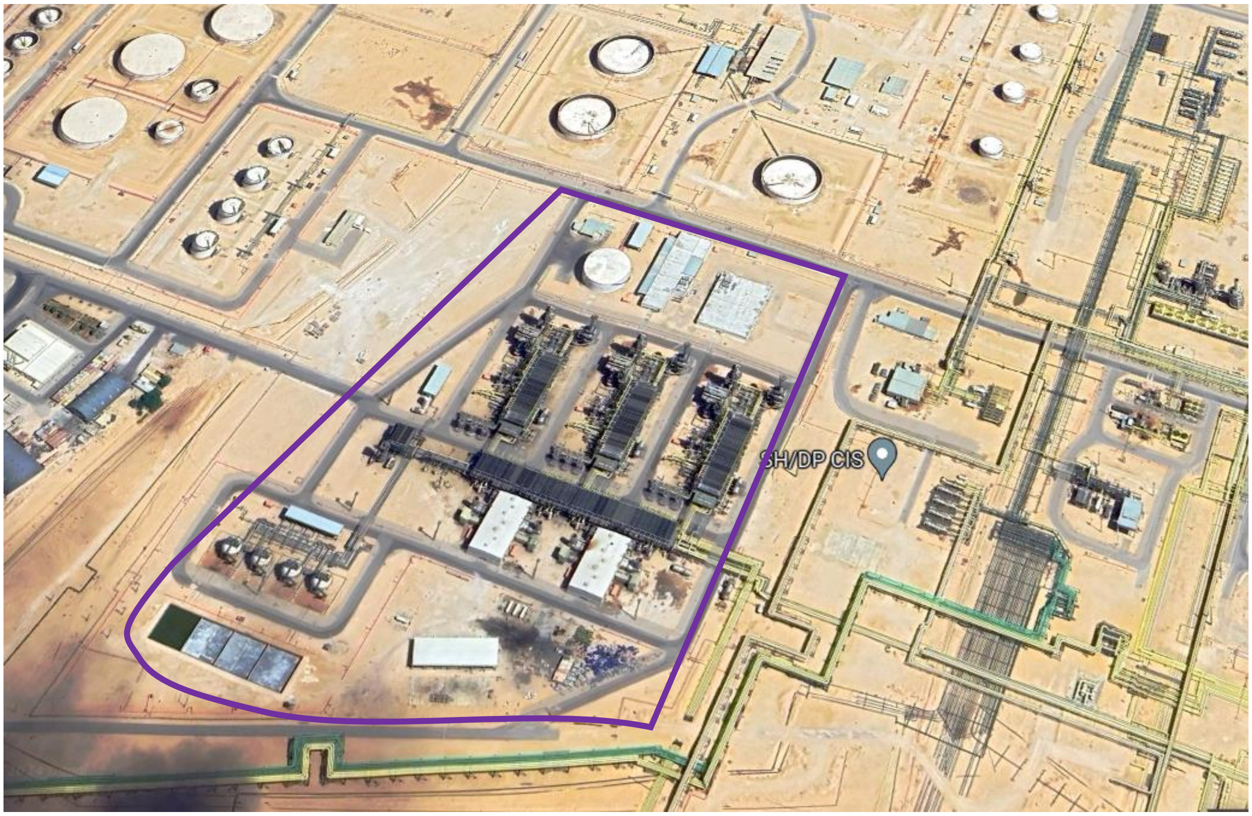
2. LPG 2 facility

All of the information in this heading are obtained from reference 6 except figure 1.2

2.1 Geographical location:

LPG 2, situated in the oil field of Hassi Massoud, is located at a distance of around 550 kilometers from the Mediterraniean Sea.

Its decimal degrees are 31.670537284734845, 6.0531774744468985.



Source:google maps

Figure 1.2 The geographical location of LPG 2 facility

2.2 Presentation:

Sonatrach and the Japanese Corporation JGC (Japan Gasoline Corporation) collaborated to commission the LPG 2 facility in July 1997. The National Company for Major Petroleum Works handled most of the work on the project. Algerian businesses handled the construction, with JGC supervising the engineering portion. The project took 34,560 working hours in total, and on January 5, 1997, manufacturing began using a combined workforce of Japanese and Algerians. The Haoud-El-Hamra pumping station is used by the LPG2 unit to extract propane and butane from the feed gas charge for transportation to Arzew. Additionally, part of the produced LPG undergoes fractionation in the depropanizer to yield commercial propane and butane, which are then supplied to the Naftal bottling center in Hassi-Messaoud for domestic use. Stabilized condensate obtained from the debutanizer is redirected to crude, while some residual gases, mainly methane and ethane serve as fuel for gas turbine boosters and furnaces. The LPG produced in the facility is about 4980 ton per day.

2.3 Treatment and production capacity

	Treatment capacity (Sm^3/day)		
	Design	**Actual**	**Lean gas**
Gas feed	24 000	26 000	24 000

Table 1.1 treatment capacity [6]

	Production capacity		
	Design	**Actual**	**Lean gas**
LPG	4490	3800	2650
Condensate	1050	800	600
Propane	240	240	240
Butane	160	160	160

Table 1.2 production capacity [6]

2.4 LPG 2 outline

The facility comprises three identical trains and includes several sections divided by their operational functions. [5]

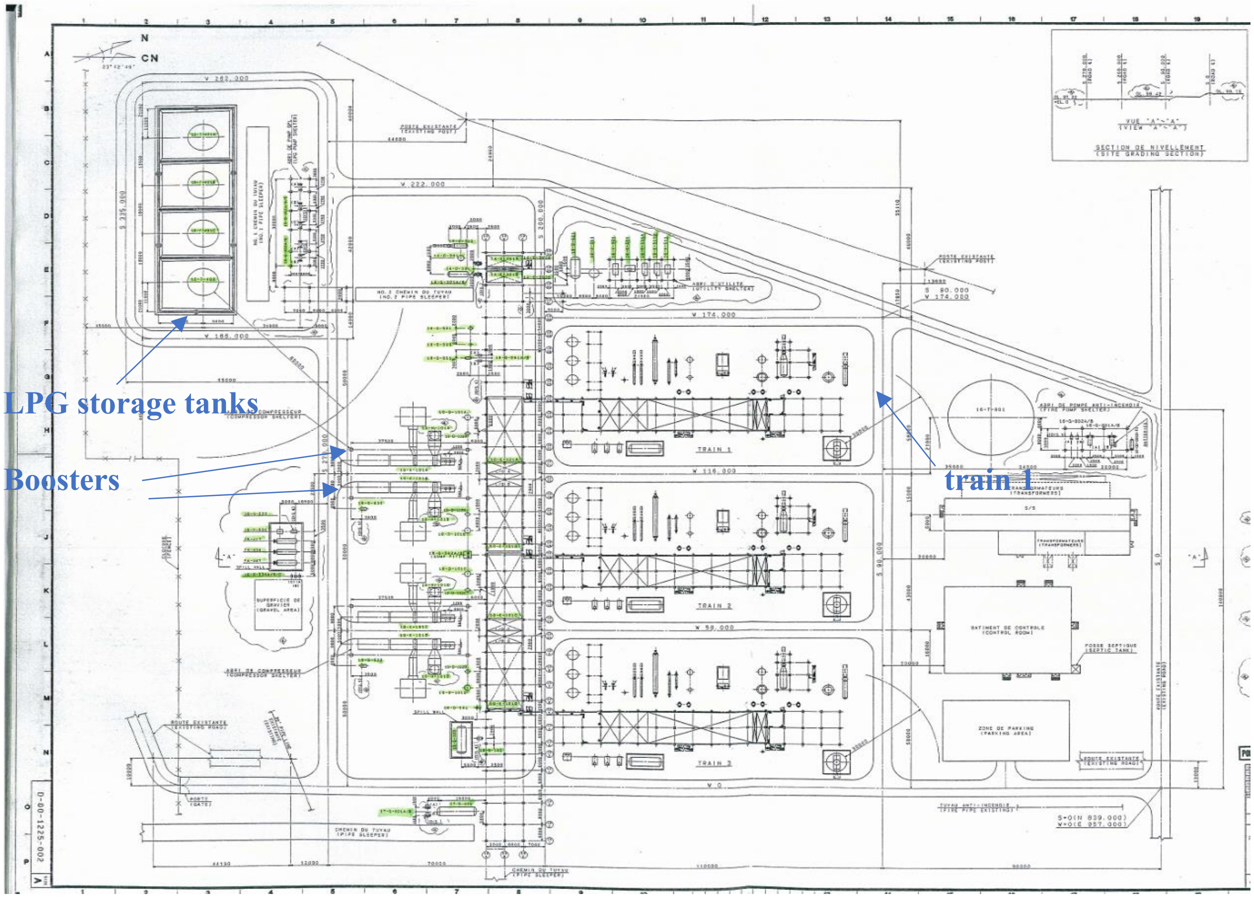


Figure 1.3 General plot plan for process area LPG 2 [6]

The facility contains the following sections:

- Manifold Section
- Boosting Section
- Dryer Section
- Cooling and Expansion Section
- Fractionation Section
- Recompression Section

- Hot Oil System
- Depropanizer
- Storage and Pumping Section
- Control Room
- Utilities Section
- Fire Protection Installations

2.5 The three industrial trains

2.5.1 Description

The LPG 2 facility comprises three identical trains dedicated to the processing of liquefied petroleum gas (LPG). Each train is equipped with the same machinery, sensors, instrumentation, and control mechanisms,

The Three trains are as uniform and efficient as one another, ensuring seamless operation within the facility. The trains operate in collectively to enhance the facility's overall capacity to handle large volumes while maintaining consistent quality and safety standards.

The pieces of equipment within are designated using a specific format: two digits, a letter, and another three digits, each parts separated by a dash (–).

In this designation system:

- The second digit of the first part represents the train number,
- The letter denotes the type of machine,
- The three digits in the third part indicate the machine number by type.

For example, the code 11-C-202 signifies that the equipment is a column (C) in the first train (indicated by the second digit '1') and it is the second column of this type (202).

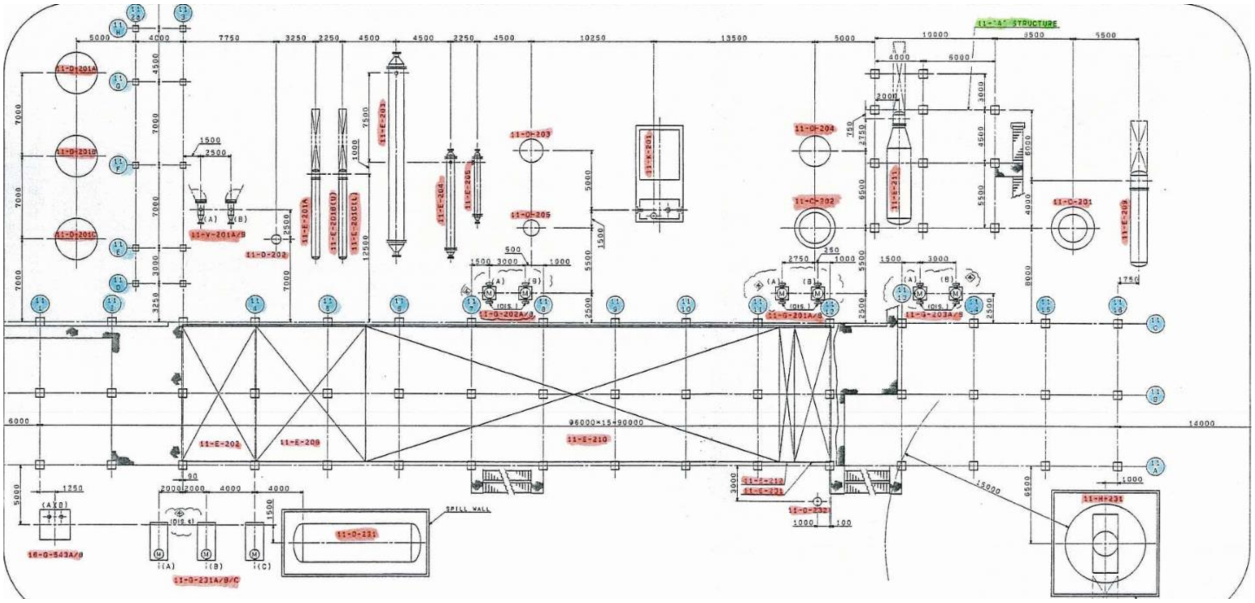


Figure 1.4 unit plot plan of train 1, 2, 3 of LPG 2 facility [6]

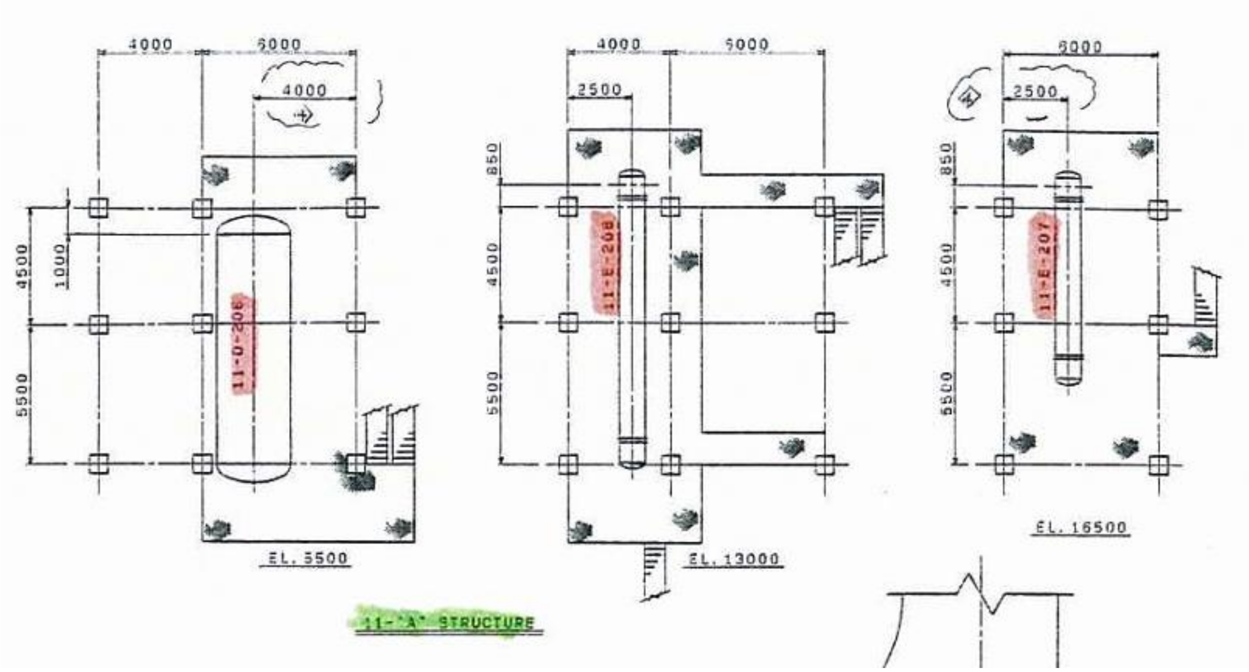


Figure 1.5 11-A- structure of the unit plot plan of train 1,2,3 [6]

2.5.2 Trains' List of machinery

Euipment tag	Equipment
11/12/13-C-201	Deethanizer
11/12/13-C-202	Debutanizer
11/12/13-D-201 A/B/C	Vapor dehydrator
11/12/13-D-202	Vapor regeneration gas seperator
11/12/13-D-203	Expander inlet seperator
11/12/13-D-204	Low pressure seperator
11/12/13-D-205	Deethanizer reflux drum
11/12/13-D-206	Debutanizer reflux drum
11/12/13-D-231	Hot oil surge drum
11/12/13-D-232	Furnace low pressure fuel gas drum
11/12/13-V-201 A/B	Vapor dehydrator outlet filter
11/12/13-E-201 A/B/C	Vapor dehydrator regeneration heater
11/12/13-E-202	Vapor dehydrator regenration cooler
11/12/13-E-203	No. 1 feed gas chiller
11/12/13-E-204	No. 2 feed gas chiller
11/12/13-E-205	No. 3 feed gas chiller
11/12/13-E-206	Exapander-compressor after cooler
11/12/13-E-207	No. 1 Deethanizer condenser
11/12/13-E-208	No. 2 Deethanizer condenser
11/12/13-E-209	Deethanizer reboiler
11/12/13-E-210	Debutanizer condenser
11/12/13-E-211	Debutanizer reboiler
11/12/13-E-212	Condensate cooler
11/12/13-E-231	Hot oil cooler
11/12/13-G-201 A/B	Deethaznier feed pump
11/12/13-G-202 A/B	Deethaznier cold reflux pump
11/12/13-G-203 A/B	Debutanizer reflux pump
11/12/13-G-231 A/B/C	Hot oil pump

11/12/13-K-201	Expander-compressor
11/12/13-H-231	Hot oil heater
16-G-543 A/B	Sump pump train. 1
16-G-544 A/B	Sump pump train. 2
16-G-545 A/B	Sump pump train. 3

Table 1.3 list of machniery of train 1, 2, 3 [6]

2.6 Sections

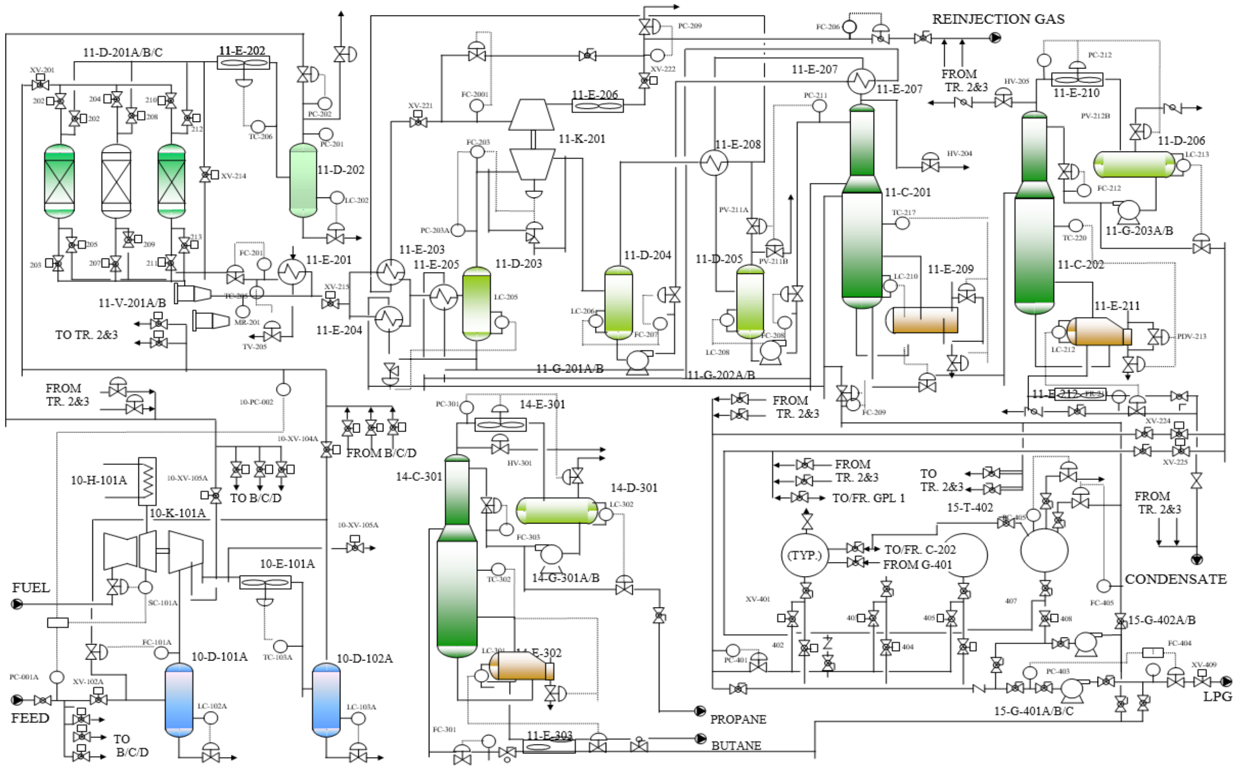


Figure 1.6 LPG 2 general process flow diagram [6]

2.6.1 Manifold Section

The gases resulting from the separation of crude oil are collected and supplied to the four trains of the two LPG units. LPG Unit-1 (one train) and LPG Unit-2 (three trains). The load capacity of this manifold is approximately 40 million Nm³/day. This manifold is equipped with safety features, thanks to the flare valves installed to handle high-pressure situations.

2.6.2 Boosting Section

The purpose of this section is to increase the pressure and flow rate of hydrocarbons. The facility contains 4 identical boosters, each contain a gas turbine to generate electricity and a compressor for gas transportation.

After being compressed in the booster compressor's suction drum D101, the feed gas exits and travels to the knockout drum (discharge drum). After being compressed from 25 bars to 97.3 bars, the cooling fan cools it to 50°C. At 96.7 bars of pressure in the knockout compressor drum D102, the circulating products are separated into gas and liquid. The output from three further boosting sections is mixed with the compressed gas from D102.

The combined circulating gases are then directed to the drying section of each of the three identical trains.

Specifications of the boosters:

- Brand of compressor and turbine: NUOVO PIGNONE (ITALY)
- Discharge flow rate: 6380 kg/min
- Rotational speed: 7340 rpm
- First critical speed: 4280 rpm
- Design pressure: 124 bars
- Discharge pressure: 98.3 bars
- Absorbed power: 2013 kW
- Maximum rotational speed: 7985 rpm
- Design temperature: 250°C

Different parts of the unit (Turbine - Compressor):

- A coupling shaft connecting (axial compressor - turbine - speed multiplier)
- An electric starting motor
- An axial compressor for ambient air intake
- A speed multiplier
- Nozzle
- High-pressure wheel

- Low-pressure wheel
- Centrifugal compressor (compresses the charge gas)
- Fuel gas flow control valves
- Three lubrication motors for the compressor - turbine bearings
- Self-cleaning system for air intake filters
- Fire detection and protection system
- Lubricating oil cooling fan
- Charge gas cooling fan after boosting section
- Suction drum D101
- Discharge drum D102

2.6.3 Dryer section

2.6.3.1 Description

Vapor dehydrators are essential components, designed to remove water vapor from feed gas to prevent the formation of hydrates, which can block pipelines and damage equipment. They also mitigate corrosion by eliminating moisture.

The feed gas exits the booster discharge manifold at 50°C and 95, and with a water vapor content of 1700 ppm. It flows from top to bottom through dryers containing type 4A molecular sieves, which reduce the moisture content to less than 5 ppm.

To prevent erosion of downstream equipment, especially the turbo expander, also to eliminate dust and desiccant particles larger than 5 microns two dust filters are placed downstream of the three dryers,. To measure the moisture content, a hygrometer is mounted on the dehydration section's outflow pipe.

The feed gas is routed to the cooling exchanger in the liquefaction stage after going through these filters.

Three fixed-bed dryers (D201 A/B/C) with a combined capacity of 35.935 tons of molecular sieves are present. Two are adsorbing, and the third dryer is regenerating simultaneously.

The table below describes the dryers' changeover procedure, which involves each dryer adsorbing for eight hours and regenerating for four.

Time (h)	0-4	4-8	8-12	12-16	16-20	20-24
D201/A	Adsorbing		regenerating	adsorbing		regenerating
D201/B	Regenerating	Adsorbing		Regenerating	Adsorbing	
D201/C	adsorbing	regenerating	adsorbing		regenerating	adsorbing

Table 1.4 dryers' changeover procedure, [6]

The regeneration loop consists of:

- Regeneration gas heaters E201 A/B/C
- One of the three dryers D201
- Regeneration gas cooler E202
- Regeneration gas separator D202

The sequences for regeneration and switching of the dryers are controlled by a timing system managed by the DCS, as indicated in the table below.

Steps	**sequence**	**Time(min)**
1	Closing the inlet and outlet valves of the dryer	1
2	Opening the regeneration valve at the inlet and outlet of the dryer	1
3	Opening the heater valves	5
4	Closing the dryer bypass valves	1
5	Heating following an ascending ramp up to 275°C	20
6	Heating at a constant temperature of 275°C	126
7	Heating following a descending ramp	15
8	Closing the heater outlet valves	5
9	Cooling	71
10	Opening the dryer bypass valves	1
11	Waiting	1
12	Closing the regeneration inlet and outlet valves of the dryers	1
13	Opening the inlet and outlet valves of the dryers	1

Table 1.5 Regeneration sequence table. [6]

2.6.3.2 Regeneration process

The regeneration process consists of two stages:

Heating Stage that takes approximately 2.7 hours:

- Heating Ramp Up: The bed is gradually heated over 20 minutes, with the regeneration gas temperature increasing from 180°C to 275°C
- Heating Steady: The regeneration gas maintains a constant temperature of 275°C for about two hours.
- Heating Ramp Down: The temperature of the regeneration gas decreases gradually over 15 minutes from 275°C to 200°C.

Cooling Stage that takes approximately 1.2 hours:

- The dry feed gas, taken downstream of the charge gas filters, is used for regeneration. It flows through the dryer from bottom to top at nearly the same pressure and at a constant rate of 54 KN^3/h, regulated by flow controller which controls the opening and closing of valves.
- The cooling cycle follows the heating cycle, cooling the bed to near adsorption temperature over 1.2 hours. During this cycle, the regeneration gas bypasses the heaters and enters the bed.

Dehydrators and filters specifications are shown below:

Equipment	**Volume (m^3)**	**Operating Pressure (bar)**	**Operating Temperature (°C)**	**Design Pressure (bar)**	**Design Temperature (°C)**	**Δp of service**
Dehydrators	84	97.7	50	110	305	0.7
Filters	1.5	96.1	50	110	85±5	0.7

Table 1.6 Dehydrators and filters specifications [6]

2.6.4 Cooling and expansion section

The gas enters the refrigeration section at a pressure of 97.6 bars and a temperature of 55°C in two parallel streams in the two exchangers E-203 and E-204 for an initial cooling to a temperature of 14.3°C. After merging in heat exchanger E-205, the two streams drop even lower to 12°C.

The product then goes into the D-203 high-pressure separator. Here, the separated liquid phase is sent to the deethanizer as a secondary feed, while the gas phase expands in the turbo-expander K-201 to a temperature of -43°C and a final pressure of 21 bars. In separator D-204, the liquid that results from this expansion is separated.

The deethanizer's overhead gases in E-208 are cooled by cold gases from D-204, which then mix with the gases from the deethanizer's reflux drum D-205 to chill the feed gas in E-203. These gases from E-208 and E-203 have respective exit temperatures of -24.2°C and 42.3°C. Prior to being sent to the reinjection unit, these leftover gases undergo compression in the K-201 turbo-expander compressor.

The liquid from D-203 feeds the deethanizer at 9°C by cooling the feed gas in heat exchanger E-204. The feed gas in heat exchanger E-205 and the above gases of the deethanizer in E-207 are cooled by the liquid from D-204. The liquid that supplies the deethanizer column C-201 comes from these exchangers, which have respective outlet temperatures of -16°C and -5.7°C.

2.6.5 Fractionation Section

The fractionation section includes the deethanizer and debutanizer columns. The deethanizer separates ethane and methane from heavier hydrocarbons, operating with feeds at different trays and using reflux and reboiling to maintain temperatures. The debutanizer further separates the deethanizer's bottom product into LPG (a mixture of propane and butane) and condensate (pentane fraction and higher)., also using reflux and reboiling to maintain the separation process.

2.6.6 Recompression Section

Extracting leftover ethane and methane gases from the gas refrigeration section is the aim of the recompression section. Gas from D-204 and product from E-208 are compressed in K-101 to 29.6 bars to create product gas. Fuel gas and treated gas are separated from the product gas after it has cooled to 50°C in the expander compressor aftercooler E-206.

The fuel gas scrubber is used to transmit the fuel gas, and the collector is used to transfer the treated gas.

2.6.7 Hot Oil section

A hot oil system is designed to ensure the heating of gas in:

- The deethanizer reboiler E-209
- The debutanizer reboiler E-211
- The depropanizer reboiler 14-E-302
- Vapor dehydrator regeneration heaters E-201-A/B/C

Figure 1.7 the industrial furnace H-231 in train 1

2.6.8 Depropanizer

The purpose of the Depropanizer is to obtain propane and butane from LPG.

In the storage section, the feed at a temperature of 55.4°C enters the propane splitter C301. The C301 operates at a service pressure of 20 bars, with a head temperature of 59.9°C and a bottom temperature of 111°C. The equipment in section C301 (dipropanizer) for propane and butane production includes the propane splitter reflux drum D301, the propane splitter condenser E301, the propane splitter reboiler E302, the propane splitter reflux pump G301 A/B, and the butane cooler E303.

The overhead products, with a flow rate of 10.446 kg/h of propane, are sent to the existing installations (NAFTAL).

The bottom liquid from C301 passes through E302 and is cooled in the butane cooler E303 to 55°C. From this, 6.211 kg/h of butane is transferred to the installations.

2.6.9 Section Storage and Pumping

The storage and pumping section includes:

- Four LPG storage spheres, each with a capacity of 500 m³, ensuring a buffer storage of LPG before shipment.
- One storage sphere, 15-T-402, with a capacity of 500 m³, intended for storing off-specification products (non-conforming products that need to be recycled for reprocessing).
- Two vertical recycling pumps, 15-G-402-A/B, that supply LPG to the depropanizer or recycle off-specification products back to the deethanizer or debutanizer.
- Three vertical shipment pumps, 15-G-401-A/B/C, with two in service and one on standby depending on the shipment flow rate.
- The produced LPG is shipped to the separation units in Arzew via an export pipeline, passing through a pumping station located approximately 20 km away at Haoud-el-Hamra.

2.6.10 Control Room

The control and command system for the trains is managed by a Distributed Control System (DCS) from Yokogawa, with eight control consoles. The booster control system is managed by General Electric's Mark V system.

2.6.11 Utilities Section

- Fuel Gas System:

The fuel gas source is derived from the residual gas returning to the reinjection stations (dry gas). This gas supplies:

- Four gas turbines at a pressure of 6 bars.
- Three furnaces H-231 at a pressure of 1.5 bars.
- Four pilots of the flare network at a pressure of 1 bar.

- Instrument and Service Air Network:

The air, supplied by the axial compressors of the gas turbines and screw air compressors, serves:

- For service air needs (unit requirements, blowing, cleaning, etc.).
- For instrument air (dried by alumina air dryers) for control valves and unit instrumentation.

- Nitrogen Production Unit:

For safety, procedures require inerting tanks or equipment before any hot work (welding, torch). A nitrogen production unit has been installed to produce gaseous nitrogen with 98% purity and a flow rate of approximately 300 Nm^3/h. The inert gas system consists of:

- Inert gas generator 16-V-521.
- Inert gas compressor 16-K-521.
- Inert gas reservoir 16-D-521.

The inert gas is transferred from 16-V-521 to 16-K-521 after passing through 16-D-521 and is then distributed throughout the LPG 2 plant via a distribution network.

2.6.12 Fire Protection System:

- Firewater pumps
- An 8500 m³ conical-roof reservoir
- Surface water intakes
- Fire hose cabinets
- Exterior hose reel stations
- Fixed monitor nozzles
- Fire extinguishers
- Cooling water system
- Carbon dioxide extinguishing system
- Dry powder extinguishing system
- Fire alarm system
- Smoke detectors
- Heat detectors
- External call station

Conclusion

In this chapter, we presented the LPG 2 facility, with its geographical locations, treatment and production capacities, and its various operational sections.

Chapter II

Instrumentation and control engineering

Introduction

In this chapter, we present key concepts in instrumentation and control engineering. We will also discuss the control strategies used in the deethanizer, providing an in-depth understanding of how these techniques are applied to optimize and maintain the process.

1. Instrumentation and control engineering

Instrumentation and control engineering is the discipline that focuses on the automation and optimization of industrial processes. It entails the planning, creation, and upkeep of systems that monitor and regulate process factors like pressure, temperature, flow, and level. Sensors that monitor changes in process variables, transmitters that translate sensor outputs into standardized forms, and controllers that use these signals to inform choices in order to maintain desired setpoints are the major parts of these systems. [6]

Controllers can be distributed control systems or programmable logic controllers or any other type [6]. control valves are examples of actuators that receive signals from these controllers and modify operations to accomplish desired results [7].

2. DCS

Distributed control systems (DCS) revolutionize industrial automation by decentralizing control functions across a network of interconnected nodes. DCS, in contrast to typical centralized systems, disperses data collecting, monitoring, and control logic among several nodes positioned strategically around a plant or facility. DCS makes it possible for nodes to communicate in real time, which makes process coordination and synchronization easier. This results in safety improvements and efficient production. [8]

3. HMI

A Human-Machine Interface, or HMI, is a system that enables interaction between operators and machines or processes. Although a screen that allows a user to interact with any kind of device can be called an HMI, industrial processes are the context in which the term is most commonly used. [9]

It consists of hardware and software that provide a display of information visually and let operators to see real-time data, control machinery with command input, monitor system performance, and modify process settings instantly. [9]

4. PLC

PLC stands for programmable logic controller which is An industrial computer built for production processes, such as assembly lines or robotic devices, where dependable control, simplicity of programming, and problem diagnosis are critical. To automate a machine or process, it keeps an eye on inputs, makes decisions according on its programming, and regulates outputs.[10]

5. PID controller

5.1 PID theory

A PID (Proportional-Integral-Derivative) controller is a control loop mechanism widely used in industrial control systems. It continuously calculates an error value as the difference between a desired setpoint and a measured process variable. The controller sums the proportional, integral, and derivative terms to calculate the output of the PID controller. [11]

The output is defined as [11]:

$$u(t)= \mathrm{KP}\, e(t)+ \mathrm{KI} \int_0^t e(t)\mathrm{d}t + \mathrm{KD}\frac{\mathrm{de(t)}}{\mathrm{dt}}$$

$$u(t)= \mathrm{KP}\, (e(t)+ \frac{1}{\mathrm{Ti}} \int_0^t e(t)\mathrm{d}t + \mathrm{Td}\frac{\mathrm{de(t)}}{\mathrm{dt}})$$

in which:

- KP is the proportional gain
- KI is the integral gain
- KD is the derivative gain
- $e(t) = ST - PV(t)$ is the error (ST is the set point and PV(t) is the process variable)
- Ti is the integral time.
- Td is the derivative time

5.2 Proportional action

the Proportional (P) action adjusts the output abased the error, which is the difference between the set point and the process variable. If the error is large, the correction applied is significant; if the error is small, the correction is minimal. It helps in bringing the process variable closer to the set point but cannot eliminate the steady-state error alone. [13]

$$\text{Proportional} = \text{KP}\ \text{e(t)}$$

5.3 Integral action

The Integral (I) component accumulates the error over time and corrects any residual steady-state error that the proportional action alone cannot eliminate. this component addresses any persistent offset between the process variable and the set point. It ensures that even small, consistent errors are corrected, thereby eliminating steady-state errors that the proportional component cannot fix. [13]

$$\text{Integral} = \text{KI} \int_0^t e(t)\text{dt} = \frac{\text{KP}}{\text{Ti}}$$

5.4 Derivative action

The derivative action responds to the speed at which the error is changing. By reacting to the error's rate of change, it helps to anticipate future errors and apply corrective actions in advance. This improves system stability and reduces oscillations, leading to a smoother response. If the sensor feedback signal is noisy or if the control loop rate is too slow, the derivative response can make the control system unstable. [13]

$$\text{Derivative} = \text{KD} \frac{\text{de(t)}}{\text{dt}} = \text{KP Td}$$

6. Split range controller

A split range controller is a type of process control system used to manage a single process variable with two or more final control elements, such as valves, that operate over different segments of the controller's output range. This allows for more precise control in processes that require multiple modes of operation or where the range of control needs to be extended beyond the capability of a single control element. [14]

Controller Output Range Division is one of split range controllers main aspects. The output signal from the controller (typically 4-20 mA or 0-100%) is divided into separate segments, each corresponding to a different control element. For instance, one valve might operate from 0-50% (closed for an output of 0% and opened for output of 50%), while another operates from 50-100% (closed for an output of 50% and opened for output of 100%). [14]

As the process variable changes, the controller adjusts the output signal, which sequentially activates each control element within its assigned range. For example, as the output increases from 0 to 100%, the first valve might fully open at 50%, after which the second valve begins to open. [14]

7. Cascade controller

A cascade controller is an advanced control strategy used in process control systems where two or more controllers are arranged in a hierarchical manner. The primary (or master) controller sets the setpoint for the secondary (or slave) controller, creating a nested control loop structure. Cascade control can only be used if the inner loop is at least as 3 times fast as the outer loop. [15]

8. Piping and instrumentation diagrams

A physical process flow's piping and associated components are shown in depth in Piping and Instrumentation Diagrams (P&IDs), which are schematic illustrations. These schematics provide crucial details for the system's design, functioning, and upkeep by illustrating how pipelines, valves, machinery, and instrumentation are arranged in a processing facility. With their ability to show how components are connected and managed to produce the intended process results, P&IDs are an invaluable resource for engineers and technicians. [16]

Engineers read and understand P&IDs the by familiarizing themselves with standard symbols, abbreviations, and notations, understanding the layout and flow direction, and identifying major equipment and control loops.

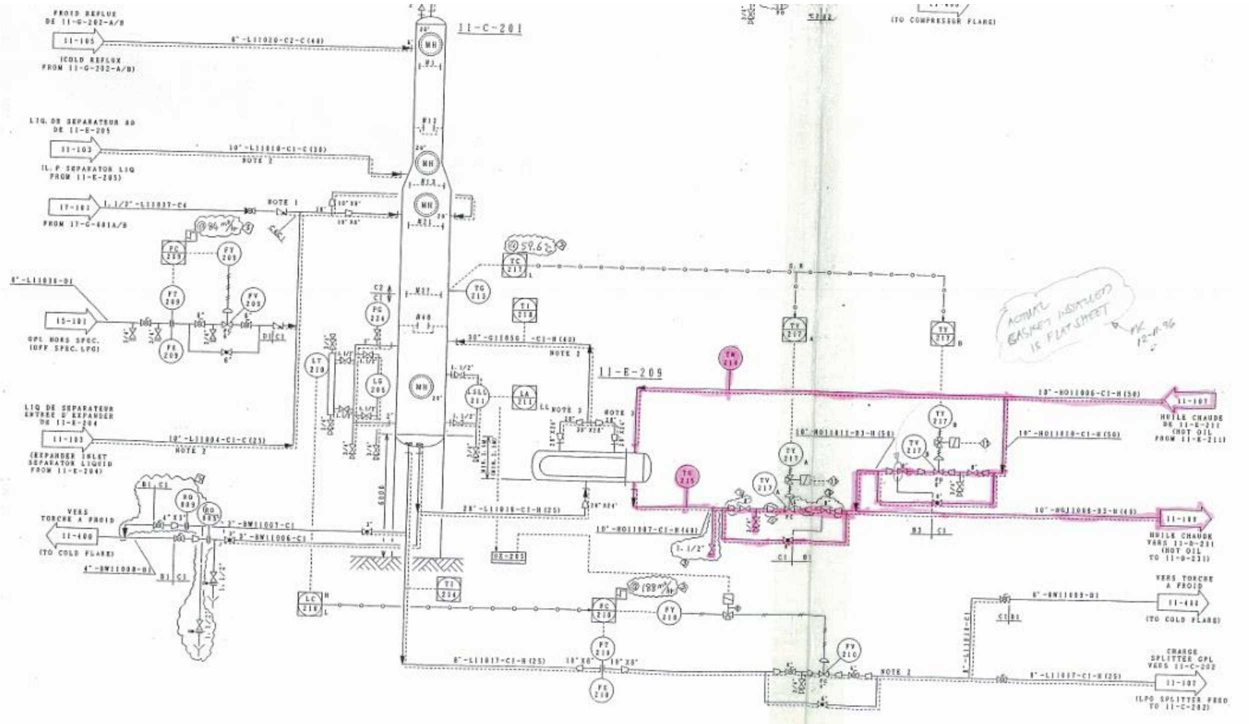


Figure 2.1 Piping and instrumentation diagram of the 11-C-201 deethanizer [17]

9. The deethanizer 11-C-201

9.1 Principle of operation

A distillation column is an industrial apparatus used to separate a mixture of liquids into its individual components based on differences in their boiling points. there are several types of distillation columns, and the deethanizer falls under the category of continuous distillation columns that operate with fractionation distillation. [17]

The 11-C-201 column is designed to separate ethane and methane from hydrocarbons such as propane, butane, and other heavier ones. The column allows the mixture to enter at two specific points, As the mixture ascends through the column, the temperature gradient causes lighter components like ethane to vaporize and rise, while heavier components to fall. [17]

Figure 2.2 The deethanizer 11-C-201

9.2 Components [16]

The column

It consists of a tall, vertical, metallic cylindrical shell equipped with a series of internal trays. These trays allow the contact between rising vapor and descending liquid. [17]

The reboiler 11-E-209

The reboiler is designed as a horizontal cylindrical vessel conjoined with two hemispherical ends to form a single container. Its primary function is to transfer heat from the hot oil to the circulating liquid, operating similarly to a heat exchanger as it contains heat exchange tubes. The heating is provided by the H 231 industrial furnace. [17]

Figure 2.3 train 1 deethanizer's reboiler

The condensers 12-E-207 12-E-208

the condensers are heat exchangers located at the top of the column. Their function is to cool and partially condense the overhead vapor stream (to, which primarily consists of ethane and methane. The liquid and gas are then transferred to the reflux drum. [17]

In any industrial setting, including this context, a single condenser is typically sufficient for the task. However, to maximize the efficient use of the thermal energy stored in the gas, the heat from the condensed vapor can be repurposed to cool other gases within the facility, thereby meeting various operating requirements and improving overall energy efficiency. [17]

The reflux drum 11-D-205

A reflux drum generally known as a condensate drum or an accumulator is a container that collects and stores condensed liquid from the overhead vapor stream.

It returns condensed liquid as reflux to the column through the first tray starting from the top.

The top overhead vapor stream is partially condensed in two heat exchangers, and the liquid is refluxed back into the column to improve separation efficiency.

This process results in a high-purity ethane product at the top.

9.3 Control aspects of the Deethanizer

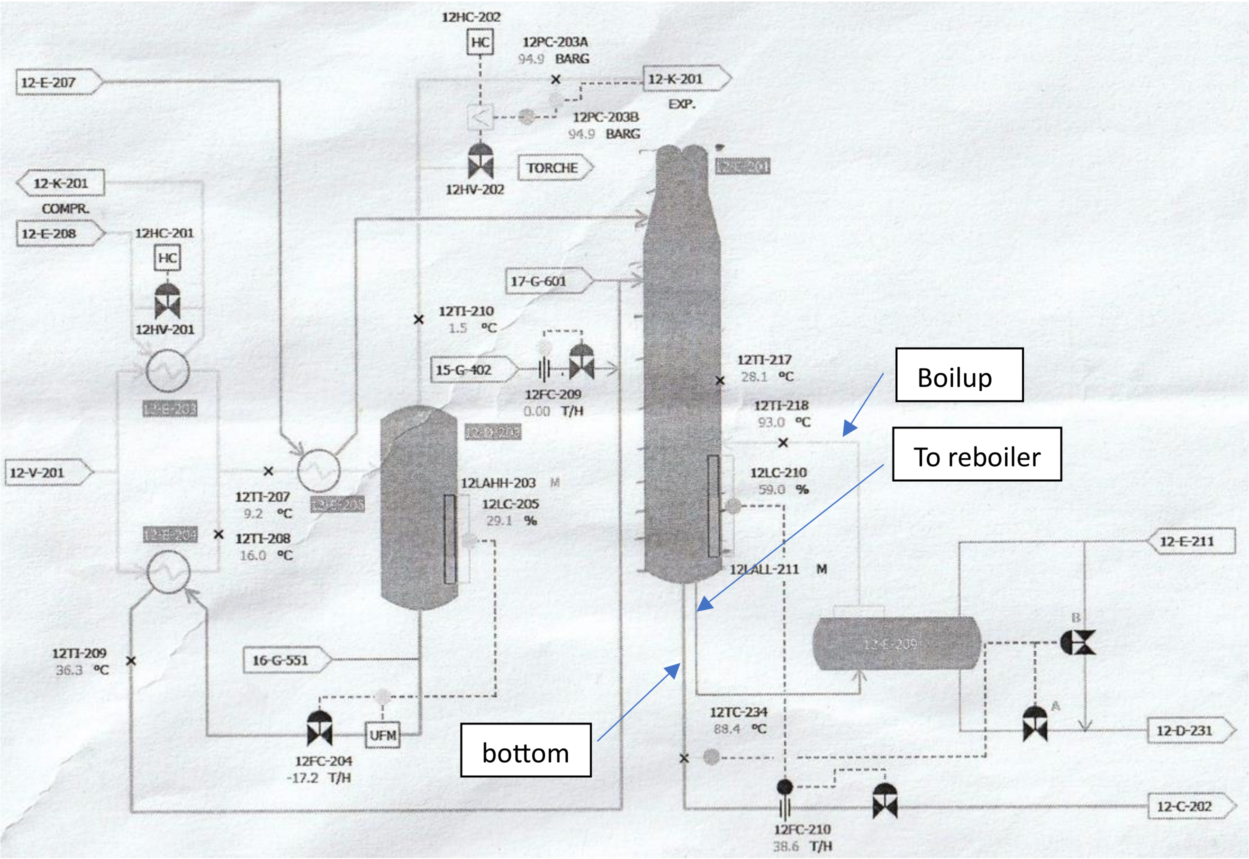


Figure 2.4 HMI printed paper of a deethanizer in train 2 first view [17]

Figure 2.5 depicts the first view of the train 2 deethanizer in the HMI. The deethanizers in the three trains are identical, with minimal differences in their operating parameters.

9.3.1 Temperature control

The split range controller is utilized to regulate the flow rate of heating oil to the reboiler, with adjustments made according to the temperature setpoint. This controller governs the valve a and the valve b as displayed in figure 2.5**.** [17]

Valve a operates from 0 to 100% of output signal (opened 0%, closed 100%) and valve b operates from 50 to 100% output signal. [17]

This precise control mechanism ensures that the deethanizer operates efficiently, maintaining the optimal temperature necessary of around 90 Degree Celsius for effective separation and maximizing the yield of ethane and heavier hydrocarbons. [17]

9.3.2 liquid Level control [16]

The displacer level transmitter continuously measures the liquid level percentage in the column. Its calculation is based on the liquid levels observed between tray 48 and tray 40. [17]

60 % of liquid level between tray 48 and 40 is the optimal operating parameter. [17]

The Controller initially established was a cascade controller. due the instability, it was replaced by a level controller. [17]

Cascade controllers in Yokogawa Centum VP and Centum CS3000 systems can be set to PRD mode (Primary Direct Mode). In this mode, the secondary (slave) controller is bypassed, the level controller is directly connected to the valve. [17]

The liquid level control in the reflux drum operates similarly to the level control in the column. Both cascade controllers were subsequently replaced with a simpler controller. And 40 percent of liquid level in the condenser is the optimal operating parameter. [17]

9.3.3 Pressure control [16]

Pressure controller controlling the pressure in the top of the column is also a split range controller controlling valve a and valve b as displayed in figure 2.6.

Valve a operates from 0 to 100% of output signal (opened 0%, closed 100%) and valve b operates from 50 to 100% output signal. [17]

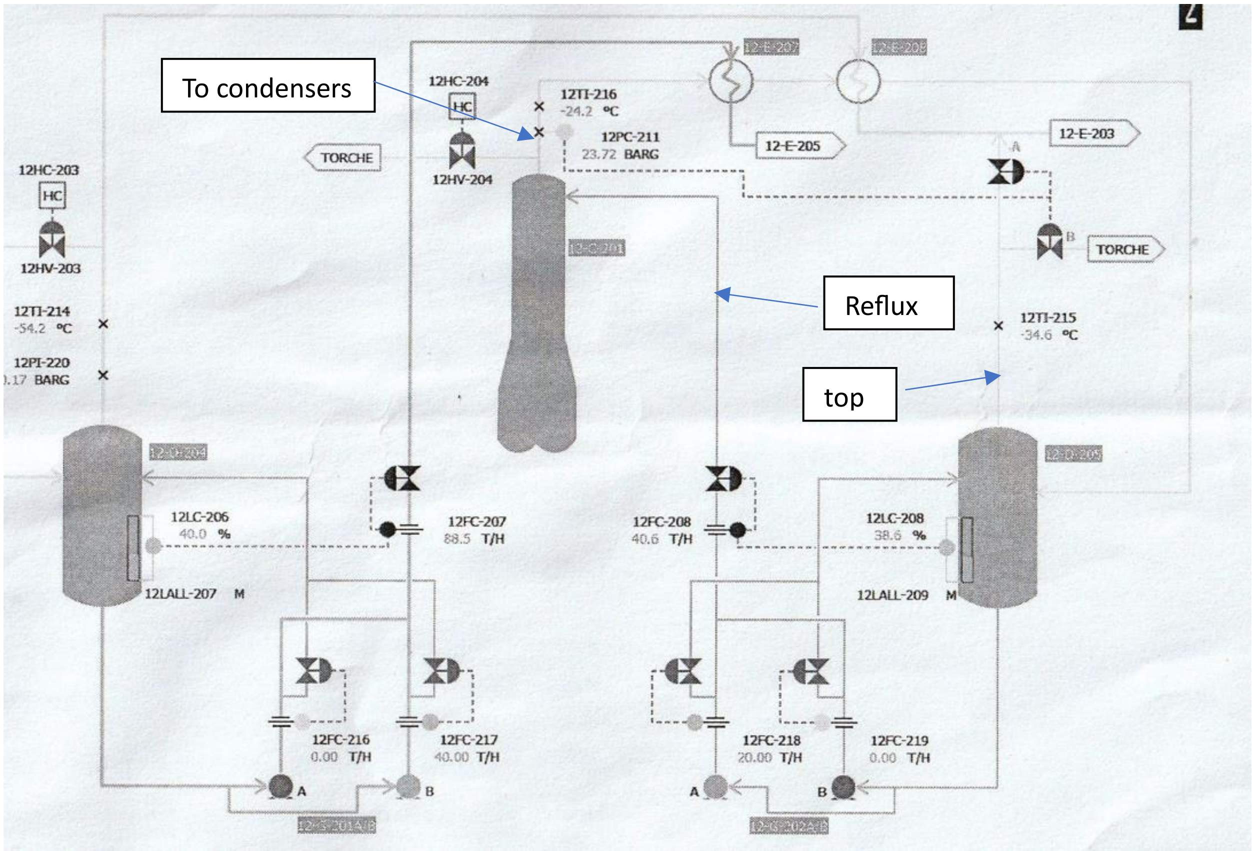


Figure 2.5 HMI printed paper of a deethanizer in train 2 second view [17]

Conclusion

In this chapter, we stated several fundamental concepts of instrumentation and control engineering. Moreover, we presented the Deethanizer 11-C-201 principle of operation and the control mechanisms utilized in it.

Chapter III

Steady state simulation

Introduction

In this chapter, we conduct a steady-state simulation, which serves as an entry point to dynamic modeling. Ensuring a correct steady-state model is important as it establishes accurate baseline conditions by defining the parameters for feed streams and the column.

1. Aspen Hysys

1.1 Description

Aspen HYSYS is a process simulation software that is widely used in the chemical engineering and process industries It provides a full environment for chemical process design, maximizing efficiency, and operation.

1.2 Characteristics and advantages

Key characteristics and advantages of HYSYS include:

- Process Simulation: HYSYS allows engineers to model and simulate the behavior of chemical processes. This includes the design of new processes and the analysis and optimization of existing ones.

- Steady-State and Dynamic Simulation: HYSYS supports both steady-state and dynamic simulations, enabling users to study both the long-term performance of a process and its transient behavior.

- Unit Operations: The software includes a wide range of pre-defined unit operation models (e.g., reactors, distillation columns, heat exchangers) that can be configured and connected to simulate complex processes.

- Thermodynamics: HYSYS offers robust thermodynamic modeling capabilities, allowing users to select appropriate thermodynamic models and accurately predict the properties of mixtures and pure components.

- Optimization: Engineers can use HYSYS to optimize process parameters for improved efficiency, cost savings, and performance. This includes economic evaluation and cost analysis.

- Safety and Risk Analysis: HYSYS provides tools for safety analysis, including the simulation of hazardous scenarios and the evaluation of safety measures.

- Integration with Other Tools: HYSYS can integrate with other engineering tools and software, such as process control systems, to provide a comprehensive solution for process design and operation.

2. Deethanizer simulation outline

In this simulation we would use a distillation column unit operation that comes with a prebuilt condenser and a reboiler.

The real-world deethanizer have two outlet bottom streams, one leaves the column and goes to the reboiler, the second leaves the column one goes to the debutanizer. The second outlet bottom stream has low mole fractions of methane and ethane.

No distillation-type unit operation in Hysys has the same outlet bottom structure as the real-world deethanizer does.

In this simulation, the outlet bottom stream exits the column and goes the reboiler, and after heat exchange in the reboiler vapor gets fed to the column and a liquid exits the reboiler.

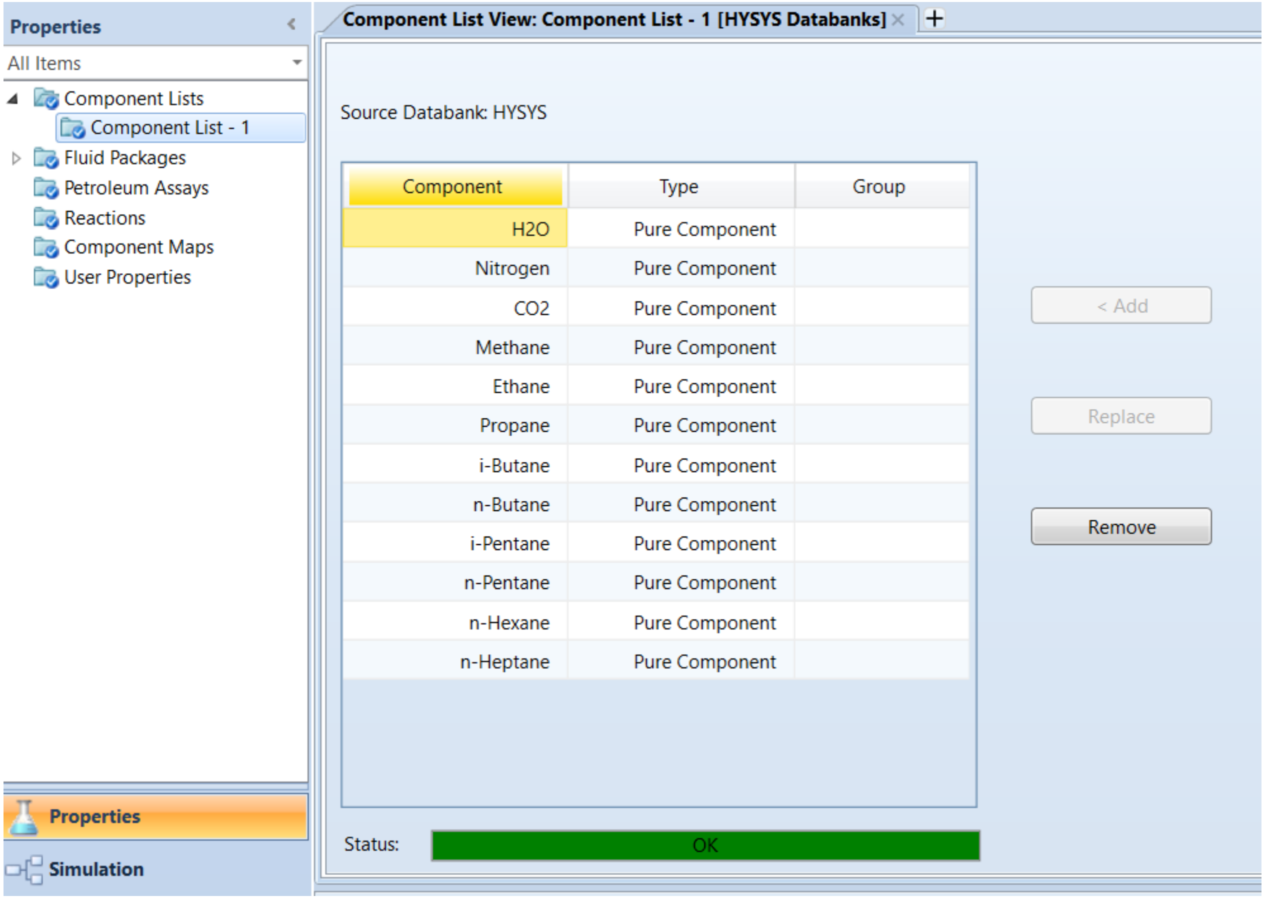
Our goal is to match the mole fraction of the outlet bottom stream from the reboiler in the simulation with the outlet bottom stream in the deethanizer and goes to the debutanizer in the real-world.

The real-world deethanizer uses two condensers to achieve its cooling requirements. In the simulation, a single condenser is modeled to replicate the function of these two condensers, accurately reflecting the cooling process of the actual deethanizer.

3. Properties environment

3.1 Components list

Component lists are groups of components which can be defined using the Components Lists folder in the properties navigation pane. a component refers to a specific chemical substance or compound that is part of the process being simulated. Components are the building blocks of any simulation.



Source Databank: HYSYS

Component	Type	Group
H2O	Pure Component	
Nitrogen	Pure Component	
CO2	Pure Component	
Methane	Pure Component	
Ethane	Pure Component	
Propane	Pure Component	
i-Butane	Pure Component	
n-Butane	Pure Component	
i-Pentane	Pure Component	
n-Pentane	Pure Component	
n-Hexane	Pure Component	
n-Heptane	Pure Component	

Status: OK

Figure 3.1 simulation components

3.2 Fluid package

The two primary elements of a fluid package are a property package, and a component list. Property packages refer to specific sets of algorithms that are used to compute a component's properties at a simulation-relevant temperature, pressure, and composition. A property package is put together with the component list after the letter has been defined.

For this particular simulation we used the Peng-Robinson fluid package.

3.3 Peng-Robinson fluid package

The Peng-Robinson (PR) model is well-suited for vapor-liquid equilibrium (VLE) calculations in hydrocarbon systems, and it is generally recommended property package for oil, gas, or petrochemical applications.

4. Entering the simulation environment

4.1 Model palette

we can utilize the Model Palette, a graphical tool in Aspen HYSYS, to create a process flow diagram by accessing different unit operation models and process components.

Usually, it consists of:

- Dynamics and control: Devices for combining or dividing process streams.
- External model: Models for simulating chemical reactions.
- Heat transfer: Equipment for separating mixtures into different phases, such as distillation columns, flash drums, and decanters.
- Manipulator: Models for simulating heat transfer between streams.
- Piping and Hydraulics: Equipment for changing the pressure of process streams.
- Pressure Changer: For pressure control and flow regulation.
- Reactor: PID controllers and other control devices for process regulation.
- separator: Components for defining material, energy, and information flows in the process.
- Material streams
- Energy streams
- Power streams

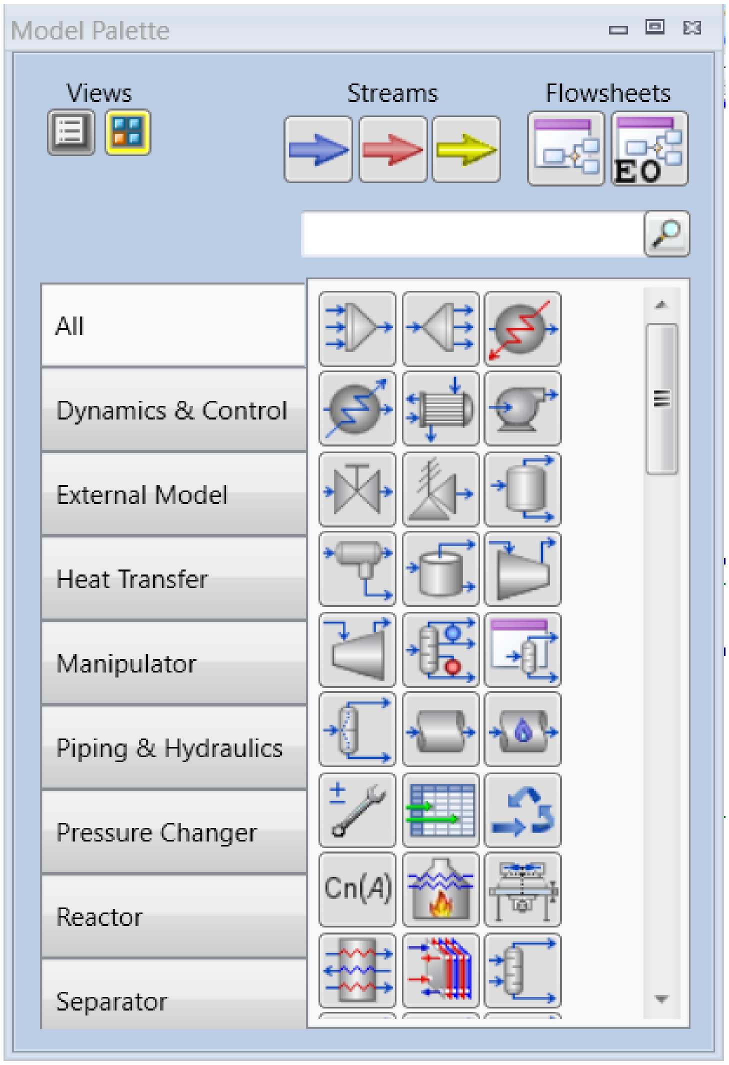


Figure 3.2 simulation environment model palate

4.2 Feed streams

4.2.1 Feed streams types

There are three types of streams in Aspen HYSYS:

- material Streams: Represent material streams. Material streams are used to simulate the flow of substances entering and exiting the operational hysys units.

- Energy Streams: refer to a type of streams that are used to represent the flow of heat energy within a process simulation. Unlike regular process streams that transport material components (e.g., fluids, gases), energy streams specifically convey thermal energy
- Power streams: they represent electrical power flows within a process simulation.

In this particular simulation only material and energy streams are required.

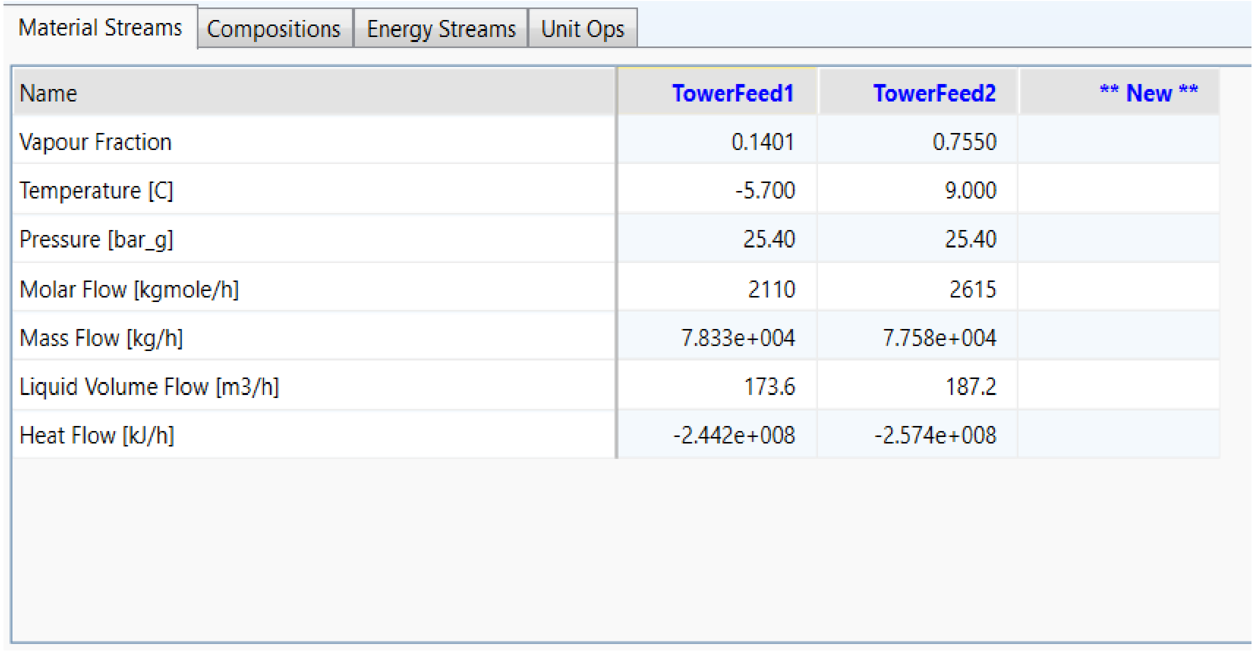
4.2.2 Defining feed streams

Defining feed streams in Aspen HYSYS involves specifying the prperties and composition of the streams that enter the simulation. This is a crucial step in setting up a process simulation as it provides the necessary data for HYSYS to perform calculations and solve the process model.

the Workbook is a versatile and comprehensive tool that allows users to organize, view, and manipulate simulation data and results in a tabular format.

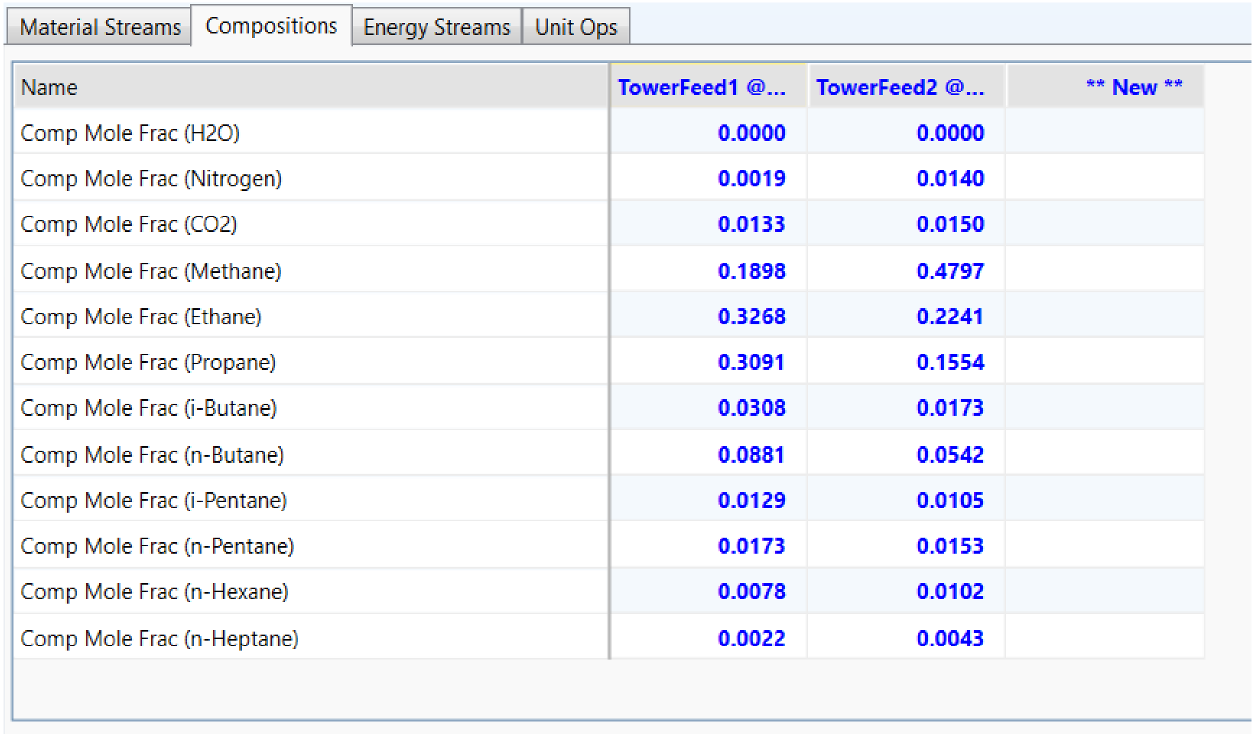
MOL %	**Components**	**TowerFeed2**	**TowerFeed1**
	H2O	0.00	0.00
	N2	1.40	0.19
	CO2	1.50	1.33
	Methane	47.97	18.98
	Ethane	22.41	32.68
	Propane	15.54	30.91
	i-butane	1.73	3.08
	n-butane	5.42	8.81
	i-pentane	1.05	1.29
	n-pentane	1.53	1.73
	n-hexane	1.02	0.78
	n-heptane	0.43	0.22
	TOTAL	100.00	100.00
Molecular Weight AMU		29.67	37.12
Molar Flow Kg mol/H		2614.9	2110.6
Mass Flow Kg/H		77578	78340
Pressure Bar_G		25.4	25.4
TEMPERATURE °C		9.0	-5.7

Table 3.1 Deethanizer material feed streams parameters and mole fractions [20]



Name	TowerFeed1	TowerFeed2	** New **
Vapour Fraction	0.1401	0.7550	
Temperature [C]	-5.700	9.000	
Pressure [bar_g]	25.40	25.40	
Molar Flow [kgmole/h]	2110	2615	
Mass Flow [kg/h]	7.833e+004	7.758e+004	
Liquid Volume Flow [m3/h]	173.6	187.2	
Heat Flow [kJ/h]	-2.442e+008	-2.574e+008	

Figure 3.3 simulation material feed streams parameters



Name	TowerFeed1 @...	TowerFeed2 @...	** New **
Comp Mole Frac (H2O)	0.0000	0.0000	
Comp Mole Frac (Nitrogen)	0.0019	0.0140	
Comp Mole Frac (CO2)	0.0133	0.0150	
Comp Mole Frac (Methane)	0.1898	0.4797	
Comp Mole Frac (Ethane)	0.3268	0.2241	
Comp Mole Frac (Propane)	0.3091	0.1554	
Comp Mole Frac (i-Butane)	0.0308	0.0173	
Comp Mole Frac (n-Butane)	0.0881	0.0542	
Comp Mole Frac (i-Pentane)	0.0129	0.0105	
Comp Mole Frac (n-Pentane)	0.0173	0.0153	
Comp Mole Frac (n-Hexane)	0.0078	0.0102	
Comp Mole Frac (n-Heptane)	0.0022	0.0043	

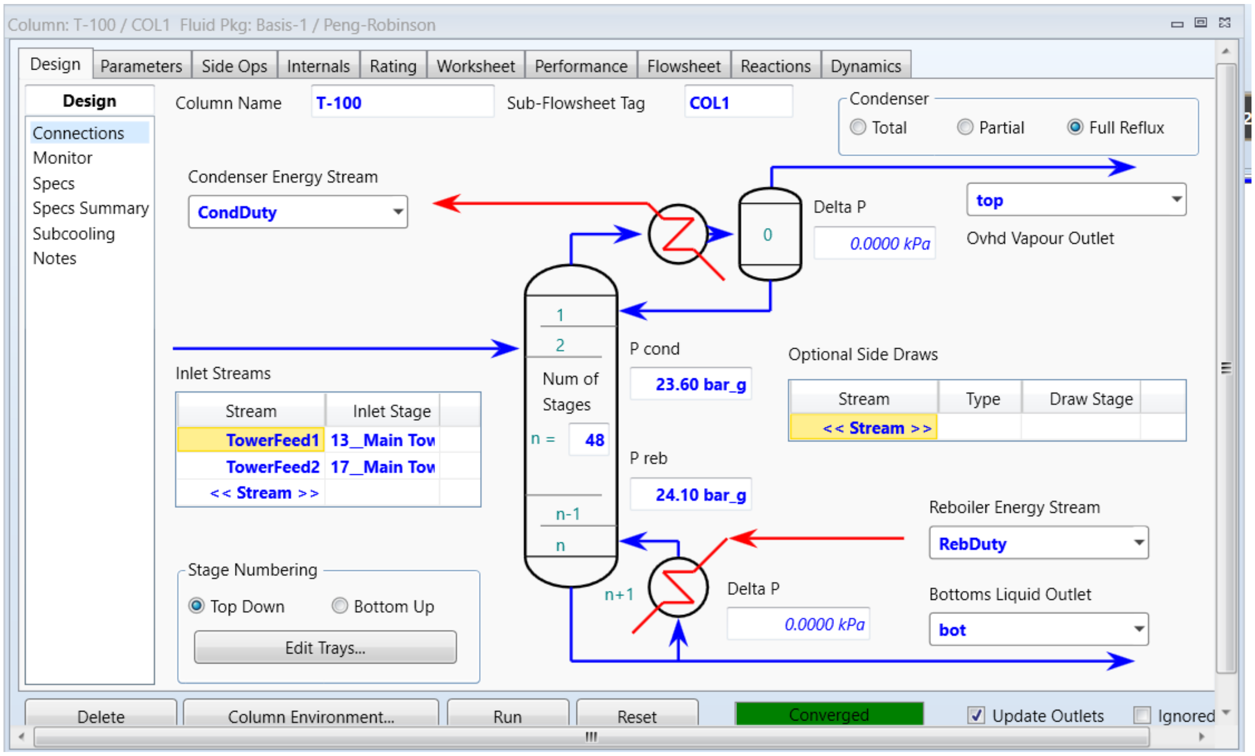
Figure 3.4 simulation material feed streams mole fractions

4.3 Adding the column specification

The deethanizer is equipped with 48 trays and has two feed points: Tower Feed 1 enters at tray 13, and Tower Feed 2 enters at tray 17. The column operates with a top tray pressure of 23.6 barg and a bottom tray pressure of 24.1 barg. The reflux is introduced at tray 1, and the boil-up is introduced at tray 48 the same as the real-world deethanizer.

This step involves adding column specification:

- Number of trays.
- Stage numbering.
- Tower feed streams and their corresponding entrance tray(stage)
- Overhead vapour outlet and bottoms liquid outlet
- Condenser full reflux
- Condenser and reboiler streams and operating pressure.



Column Name: T-100

Sub-Flowsheet Tag: COL1

Condenser: ○ Total ○ Partial ● Full Reflux

Condenser Energy Stream: CondDuty

Delta P: 0.0000 kPa

Ovhd Vapour Outlet: top

P cond: 23.60 bar_g

Num of Stages: n = 48

P reb: 24.10 bar_g

Inlet Streams

Stream	Inlet Stage
TowerFeed1	13__Main Tow
TowerFeed2	17__Main Tow
<< Stream >>	

Optional Side Draws

Stream	Type	Draw Stage
<< Stream >>		

Stage Numbering: ● Top Down ○ Bottom Up

Reboiler Energy Stream: RebDuty

Delta P: 0.0000 kPa

Bottoms Liquid Outlet: bot

Figure 3.5 column specifications

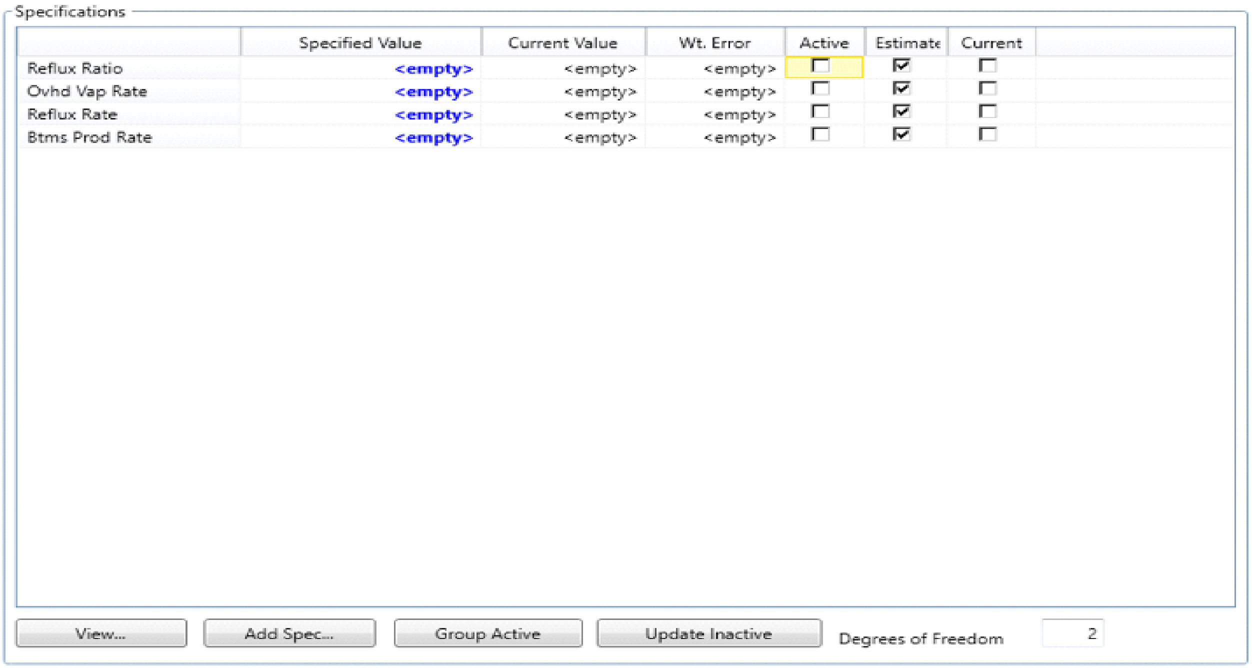
In figure 3.5 The delta P in the reboiler and condenser represents the pressure drop of the liquid. A pressure drop of 0 kPa indicates that the inlet and outlet streams of the condenser have the same pressure.

Specifically, the condenser inlet stream pressure matches the top stage pressure of the column. Given that we specified a 0 kPa pressure drop, the outlet stream of the condenser will also have the same pressure as the inlet stream.

In a distillation column the condenser outlet stream which is the reflux is by default introduced through tray 1 and the reboiler boil up is introduced through tray 48 the same as the real-world deethanizer.

4.4 Hysys degrees of freedom

HYSYS performs a degrees of freedom analysis to determine the number of independent process variables that must be defined and specified for the system to achieve convergence. The degrees of freedom represent the number of variables that need to be set to balance the system's equations and constraints. For the system to converge successfully, the degrees of freedom must equal zero. This means that all necessary variables have been specified, ensuring that the system is fully defined and solvable.



	Specified Value	Current Value	Wt. Error	Active	Estimate	Current
Reflux Ratio	<empty>	<empty>	<empty>	☐	☑	☐
Ovhd Vap Rate	<empty>	<empty>	<empty>	☐	☑	☐
Reflux Rate	<empty>	<empty>	<empty>	☐	☑	☐
Btms Prod Rate	<empty>	<empty>	<empty>	☐	☑	☐

Degrees of Freedom 2

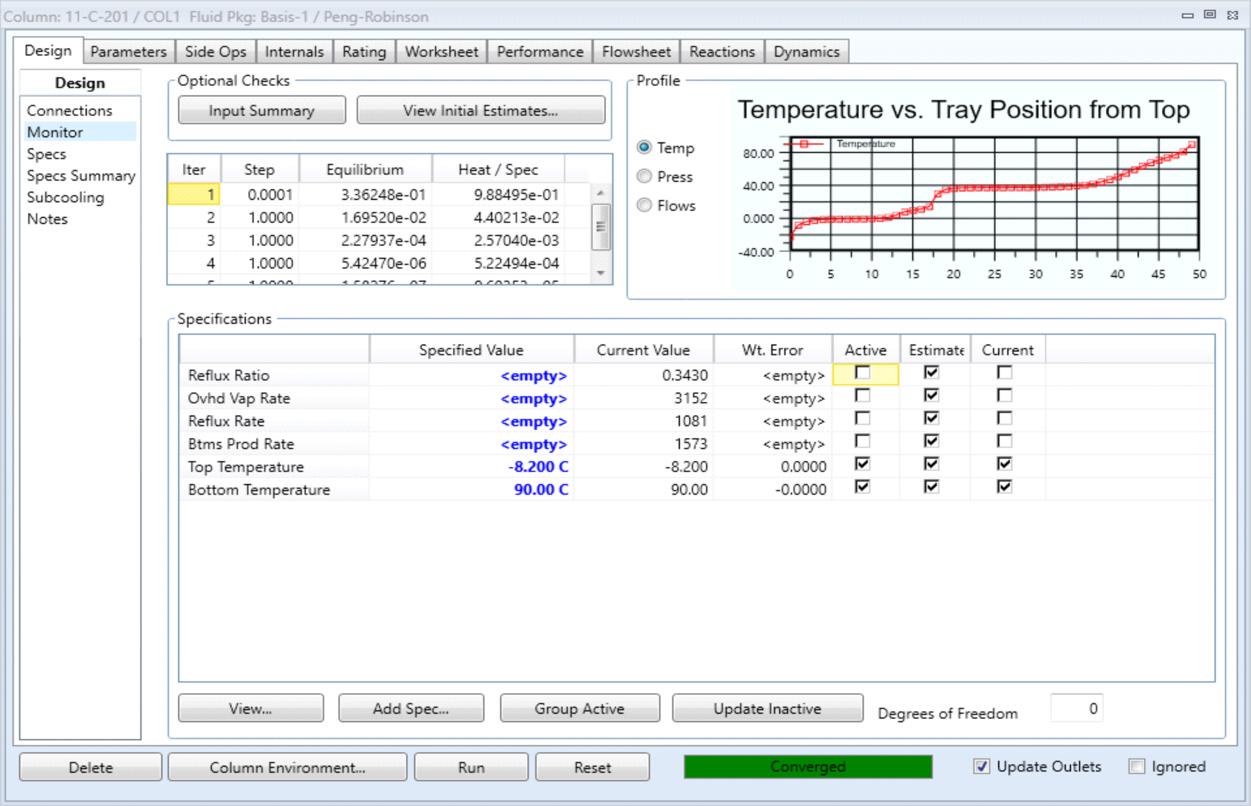
Figure 3.6 degrees of freedom panel

In Figure 3.7, 2 degrees of freedom are identified. After clicking the specification button, a list of process variables appears. To achieve convergence, we need to select 2 process variables from this list. Among the variables in the list, only the column temperature parameters are available, specifically the top stage temperature of -8.2°C and the bottom stage temperature of 90°C.

4.5 Convergence

In Aspen HYSYS, convergence means that the simulation calculations have settled and all conditions are satisfied, indicating the model is stable and correct.

Figure 3.8 is the subflowsheet view of the simulation column



Iter	Step	Equilibrium	Heat / Spec
1	0.0001	3.36248e-01	9.88495e-01
2	1.0000	1.69520e-02	4.40213e-02
3	1.0000	2.27937e-04	2.57040e-03
4	1.0000	5.42470e-06	5.22494e-04

	Specified Value	Current Value	Wt. Error	Active	Estimate	Current
Reflux Ratio	<empty>	0.3430	<empty>	☐	☑	☐
Ovhd Vap Rate	<empty>	3152	<empty>	☐	☑	☐
Reflux Rate	<empty>	1081	<empty>	☐	☑	☐
Btms Prod Rate	<empty>	1573	<empty>	☐	☑	☐
Top Temperature	-8.200 C	-8.200	0.0000	☑	☑	☑
Bottom Temperature	90.00 C	90.00	-0.0000	☑	☑	☑

Degrees of Freedom 0

Figure 3.7 column monitor page in the design tab

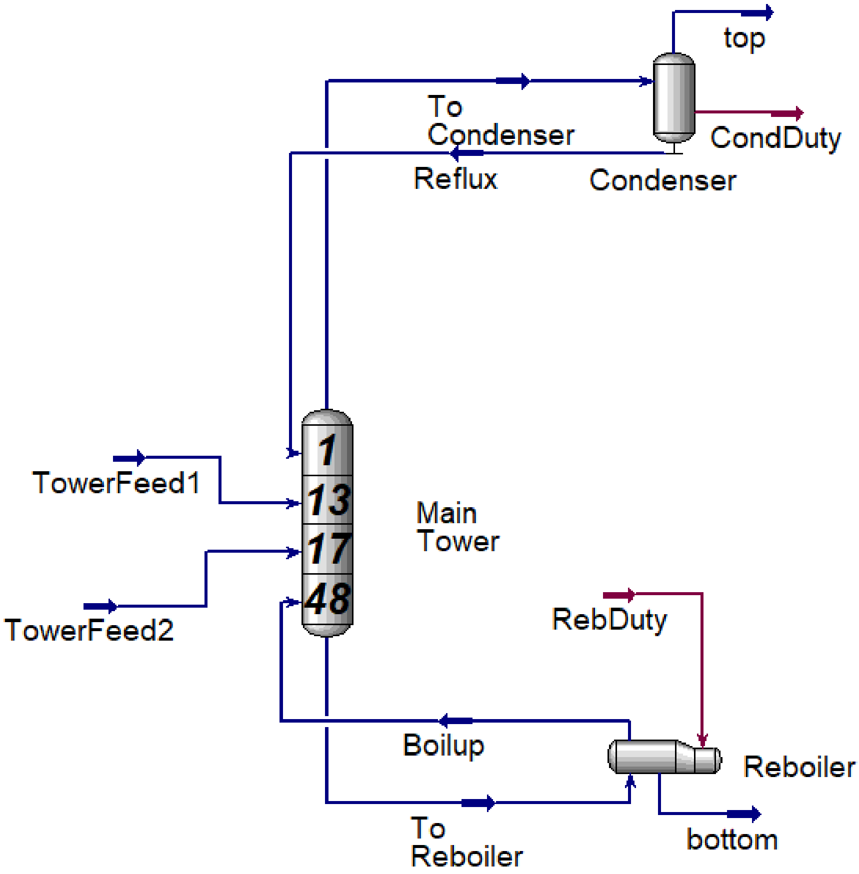


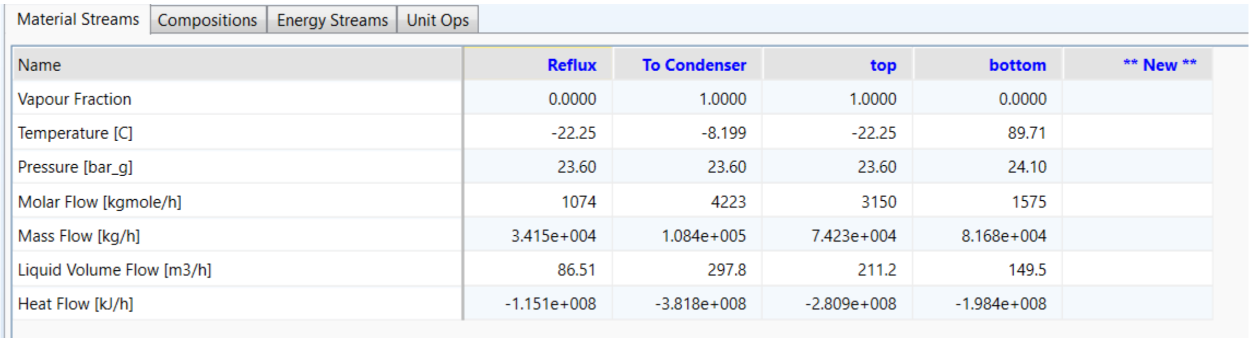
Figure 3.8 the column subflowsheet

5. Result analysis

After convergence simulation data are shown in figure 3.9 and figure 3.10

Name	Reflux	To Condenser	top	bottom	** New **
Comp Mole Frac (H2O)	0.0000	0.0000	0.0000	0.0000	
Comp Mole Frac (Nitrogen)	0.0011	0.0099	0.0129	0.0000	
Comp Mole Frac (CO2)	0.0132	0.0193	0.0214	0.0000	
Comp Mole Frac (Methane)	0.1335	0.4258	0.5254	0.0000	
Comp Mole Frac (Ethane)	0.6082	0.4512	0.3977	0.0146	
Comp Mole Frac (Propane)	0.2441	0.0938	0.0426	0.5867	
Comp Mole Frac (i-Butane)	0.0000	0.0000	0.0000	0.0700	
Comp Mole Frac (n-Butane)	0.0000	0.0000	0.0000	0.2080	
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0000	0.0347	
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0000	0.0486	
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0000	0.0274	

Figure 3.9 simulation streams mole fractions.



Name	Reflux	To Condenser	top	bottom	** New **
Vapour Fraction	0.0000	1.0000	1.0000	0.0000	
Temperature [C]	-22.25	-8.199	-22.25	89.71	
Pressure [bar_g]	23.60	23.60	23.60	24.10	
Molar Flow [kgmole/h]	1074	4223	3150	1575	
Mass Flow [kg/h]	3.415e+004	1.084e+005	7.423e+004	8.168e+004	
Liquid Volume Flow [m3/h]	86.51	297.8	211.2	149.5	
Heat Flow [kJ/h]	-1.151e+008	-3.818e+008	-2.809e+008	-1.984e+008	

Figure 3.10 simulation streams parameters

Table 3.2 shows the comparison of streams' mole fractions, with the highest percent error being 0.019% in the propane mole fraction in the reflux stream.

Table 3.3 presents the comparison of streams' molar and mass flows, with the highest percent error being 2.06% in the mass flow in the reflux stream.

Although the percent error in the mass flow is relatively higher, the differences between the simulated and actual column data are minimal. This indicates a high degree of accuracy and reliability in this simulation model.

Such a close alignment between the simulation data and real data suggests that the simulation model can be effectively used for predictive and optimization purposes, providing confidence in its application for process analysis and control strategies.

Since steady-state simulation serves as an entry point to dynamic simulation, achieving a realistic model ensures a stable dynamic simulation. A well-aligned steady-state simulation indicates that the subsequent dynamic simulation will run with minimal errors and perform effectively.

Components	**Reflux**		**To condenser**		**Top**		**bottom**	
	Real data	**simulation data**	**Real data**	**simulation data**	**Real data**	**simulation data**	**Real data**	**simulation data**
H2O	0,00	0.00	0,00	0.00	0,00	0.00	0,00	0.00
N2	0,0009	0.0011	0,0099	0.0099	0,0129	0.0129	0,00	0.00
Co2	0,0132	0.0132	0,0193	0.0193	0,0214	0.0214	0,00	0.00
methane	0,1273	0.1335	0,4263	0.4258	0,5258	0.5254	0,00	0.00
Ethane	0,6095	0.6082	0,4513	0.4512	0,3987	0.3977	0,012	0.0146

Propane	0,2489	0.2441	0,0931	0.0938	0,0412	0.0426	0,5897	0.5867
i-butane	0,0002	0.00	0,0001	0.00	0,00	0.00	0,0699	0.700
n-butane	0,00	0.00	0,00	0.00	0,00	0.00	0,2079	0.2080
i-pentane	0,00	0.00	0,00	0.00	0,00	0.00	0,0347	0.0347
n-pentane	0,00	0.00	0,00	0.00	0,00	0.00	0,0485	0.0486
n-hexane	0,00	0.00	0,00	0.00	0,00	0.00	0,0273	0.0274
n-heptane	0,00	0.00	0,00	0.00	0,00	0.00	0,01	0.0101

Table 3.2 streams mole fractions comparison.

	Reflux		**To condenser**		**Top**		**bottom**	
	Real data	**Simulation data**	**Real data**	**simulation data**	**Real data**	**Simulation data**	**Real data**	**Simulation data**
Molar Flow Kgmol/H	1047	1074	4195,3	4223	3148,3	3150	1577,2	1575
Mass Flow Kg/H	33463	34153,78	107573	108384	74110	74230	81809	81677,5

Table 3.3 Streams mole flow and mass flow comparison

conclusion

In this chapter, we conducted a steady-state simulation as a preliminary step towards dynamic simulation. Following this, through a comparative study, it was observed that the steady-state simulation closely aligns with actual plant data.

Chapter IV
Dynamic simulation

Introduction

In this chapter, we present the dynamic simulation of the deethanizer. The dynamic simulation includes a realistic model accurately represents system behavior. This allows us to integrate and analyze PID controllers in real time.

1. Difference between steady state simulation and dynamic simulation

1.1 Steady state simulation

A steady state is defined as a condition in which a system experiences little to no change over time. As the definition implies steady state simulation is time-independent, and it can be used to evaluate various plan scenarios. Design engineers may enhance production efficiency and reduce capital and equipment costs by using steady state simulations to optimize operations.

1.2 Dynamic simulation

Dynamic simulation in Aspen HYSYS is a powerful tool used to model and analyze the time-dependent behavior of chemical processes and refining operations. In contrast to steady state simulations, which postulate constant process conditions, dynamic simulation depicts how variables like compositions, temperatures, pressures, flow rates, and disturbances alter over time in response to operational modifications, control actions, and disturbances. With the help of this feature, engineers can examine behaviors in start-up, shutdown, and emergency situations, learning more about process dynamics, safety concerns, and operating limitations. Engineers may increase overall plant performance, optimize control techniques, and improve process safety by using Aspen HYSYS to precisely simulate these dynamic responses. The comprehensive understanding obtained from dynamic simulations aids in the development of reliable operating procedures and the resolution of operational problems.

2. Simulation PID equation

Hysys provides several PID controller forms the Hysys PID velocity form is the one used in this simulation and the equation is as follows:

$$u(t) = u(t-1) + Kc\,(ep(t) - ep(t-1) + \frac{h}{Ti}\,e(t) + \frac{Td}{h}\,(e_D(t) - 2e_D(t-1) + e_D(t-2)\,)\,)$$

where:

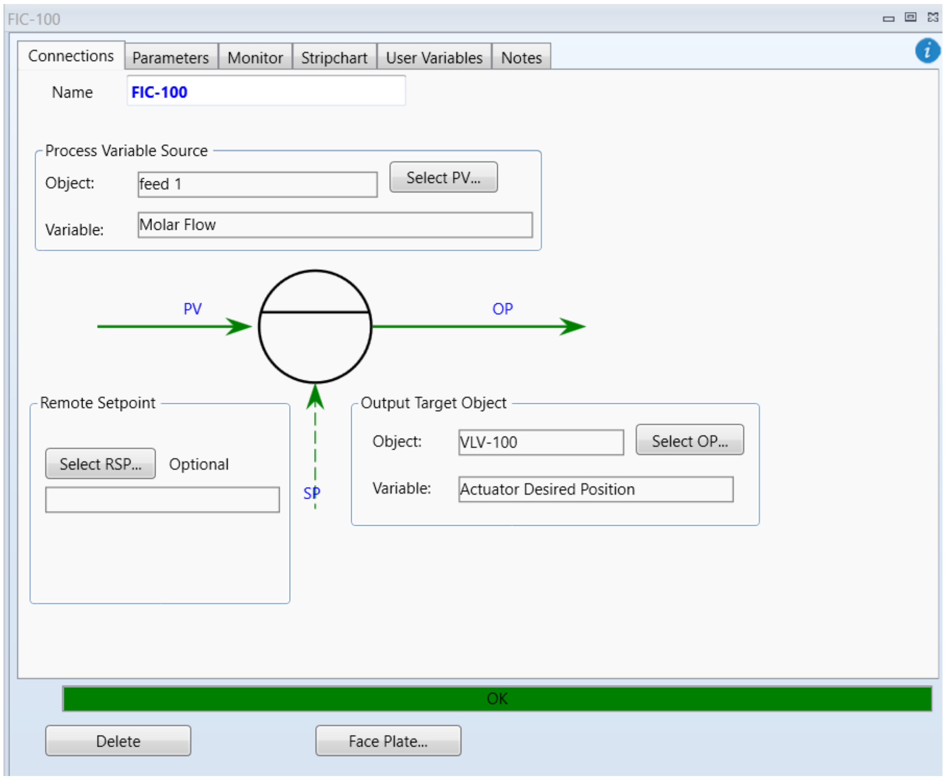
- $u(t)$= controller output and t is the enumerated sampling instance in time
- $u(t-k)$ = value of the controller output k sampling periods before
- $e(t-k) = sp(t - k) - pv(t - k)$ = value of the error signal k sampling periods before
- $ep(t -k) = b \times e(t-k)$
- $e_D(t-k) = c \times e(t-k)$
- $pv(t - k)$ = value of the process variable k sampling periods before
- Kc, Ti, Td = proportional gain, integral time, derivative time.
- h = sampling period
- sp = setpoint
- $0 \leq b, c \leq 1$
  - b = setpoint weight for proportional action
  - c = setpoint weight for derivative action

3. PID controller integration process

3.1 connections

The connection tab allow use to add important information of pid controller which are

- The name of the controller.
- The process variable object.
- The process variable.
- The output target Object.
- The remote set point source: the remote setpoint source defines the origin of the setpoint, which is specifically applicable in cascade loop configurations.



Name FIC-100

Process Variable Source

Object: feed 1

Variable: Molar Flow

Output Target Object

Object: VLV-100

Variable: Actuator Desired Position

Figure 4.1 Flow controller PID connections tab

3.2 parameters

It is necessary to define the following parameters before the controller can be functional:

- Set point
- The process variable range: the range is defined by the minimum and the maximum values of the process variable. Hysys than converts the PV range into a 0-100% range,
- Mode:
  - Off: The relevant data is still tracked, but the controller does not operate the control valve.
  - Manual: manual modification of the controller's output.
  - Auto: In response to variations in the process variable, the controller modifies the output in accordance with the tuning parameters.
  - Cascade: setting this controller as a master controller in a cascade loop.

  - Indicator: Allows you to simulate the controller without controlling the process.
- Execution:
  - Internal: Confines the signals generated to stay within HYSYS.
  - External: Sends the signals to a DCS, if a DCS is connected to HYSYS.
- Action:
  - Direct: When the PV rises above the SP, the OP increases. When the PV falls below the SP, the OP decreases.
  - Reverse: When the PV rises above the SP, the OP decreases. When the PV falls below the SP, the OP increases.

4. Dynamic simulation flowsheets

In this simulation, three controllers have been integrated. All controllers are set to automatic mode to allow them to respond to setpoint changes, enabling the fine-tuning of the PID controller parameters.

In figure 4.2 and figure 4.3 The controllers are displayed:

LIC-100: liquid indicator controller 100

LIC-101: liquid indicator controller 101

FIC-100: Flow indicator controller 100

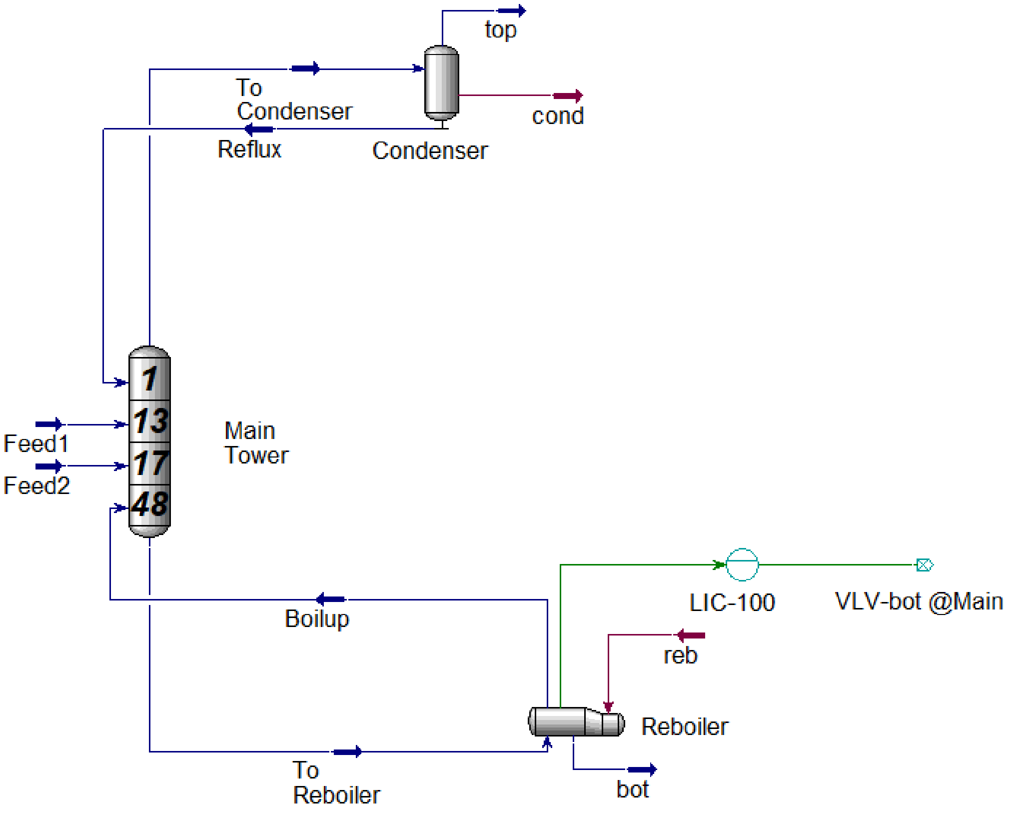


Figure 4.2 Subflowsheet view

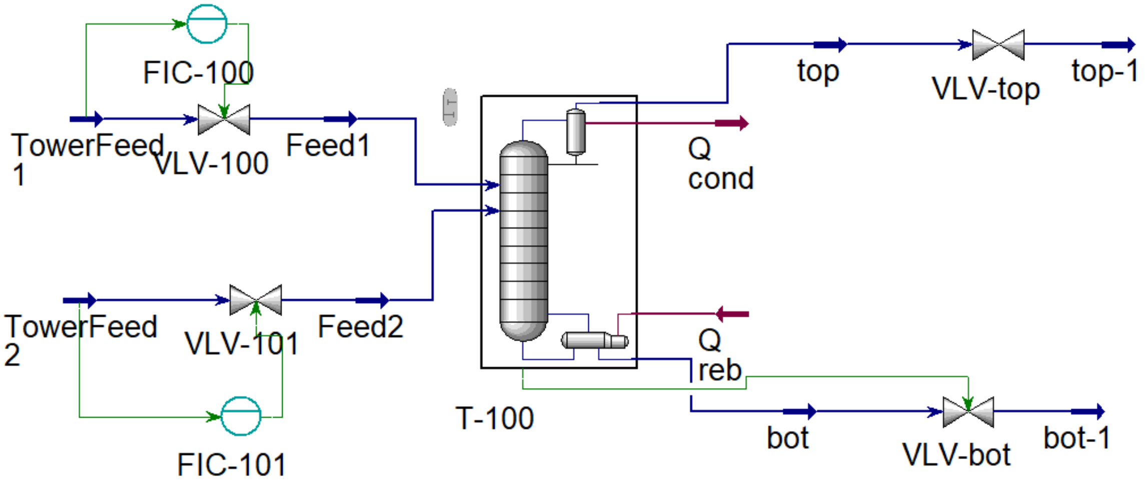


Figure 4.3 Flowsheet view

5. Flow controllers

To assess how flow controllers respond without PID parameters, we can either conduct dynamic simulations, manually adjust set points, and employ trial and error for PID tuning, or use a step signal test; The latter was used in the flow controllers.

Hysys provides 3 parameters of step test signal Variation Amplitude sets the extent of set point changes. Time Interval dictates data recording frequency during testing. Testing Time Length should exceed the system's time constant for effective evaluation.

Controller	PV	Output target	Action	Kc	Ti	PV min	PV max	SP
FIC-100	Molar flow @Towerfeed 1	VLV-100	Reverse	0,200	0,250	0 Kgmole/h	2150 Kgmole/h	2000 Kgmole/h
FIC-101	Molar flow @Tower feed2	VLV-101	Reverse	0,200	0,250	0 Kgmole/h	2650 Kgmole/h	2500 Kgmole/h

Table 4.1 flow controllers operating parameters

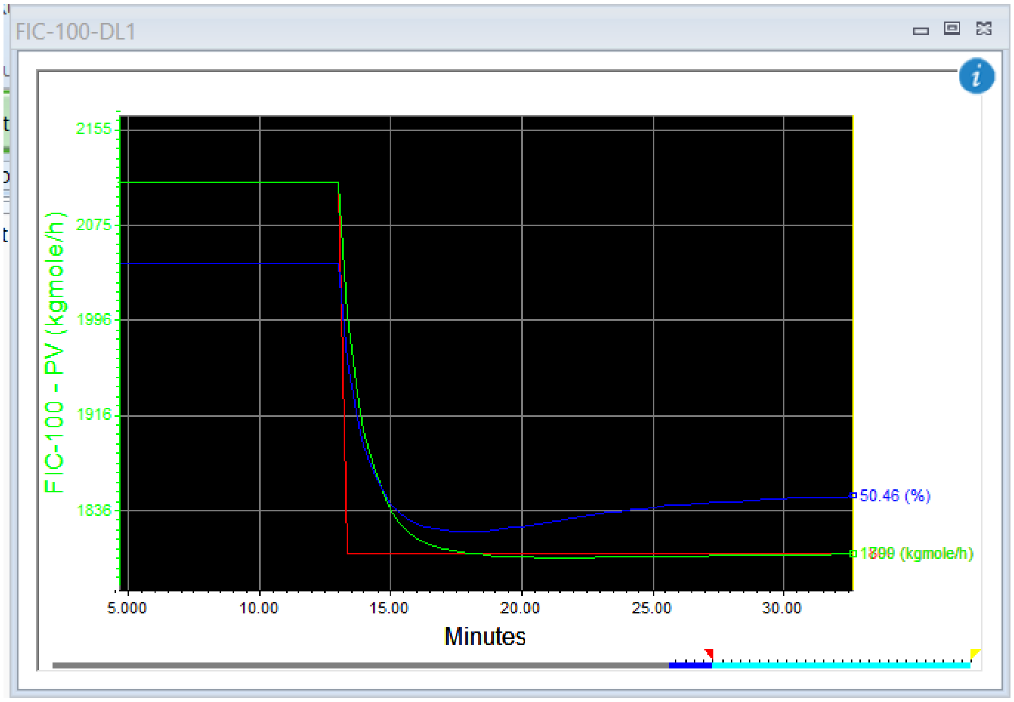


Figure 4.4 FIC-100 negative setpoint change response

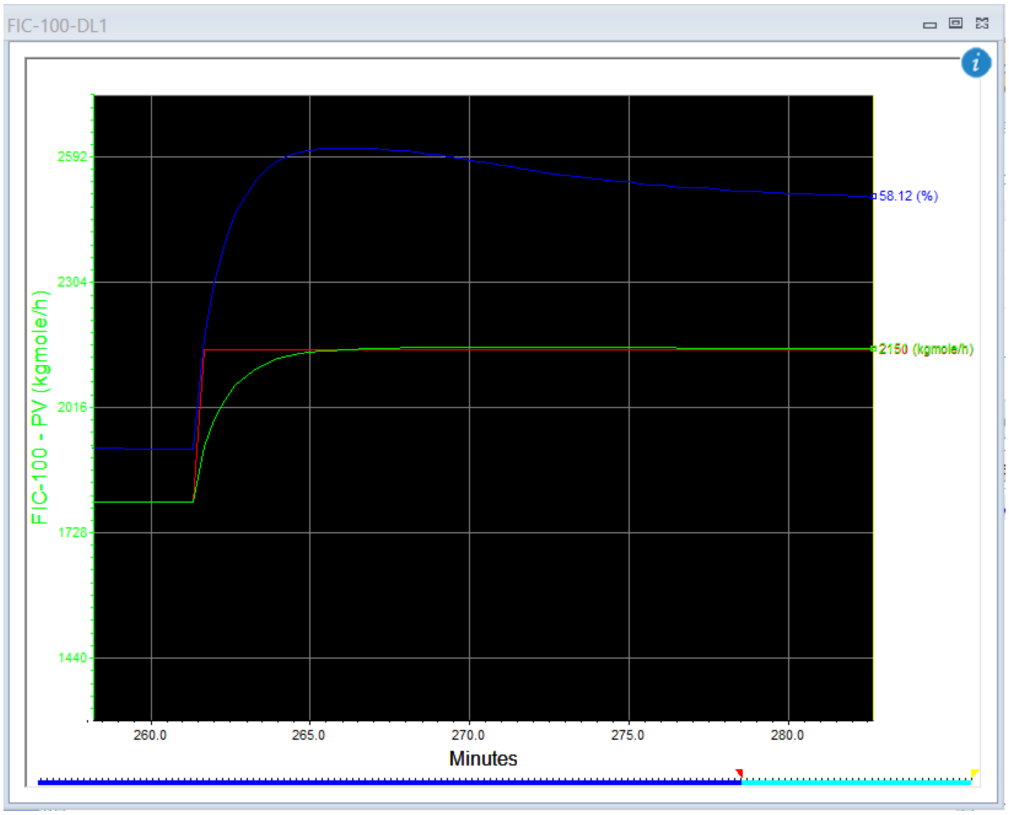


Figure 4.6 FIC-100 positive setpoint change response

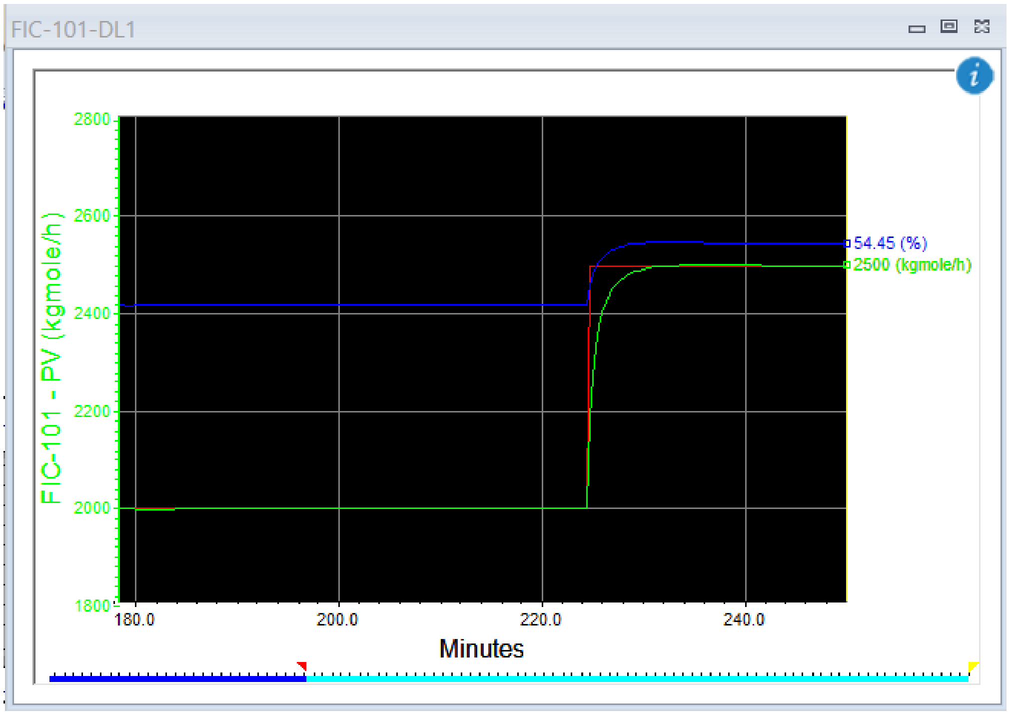


Figure 4.7 FIC-101 positive setpoint change response

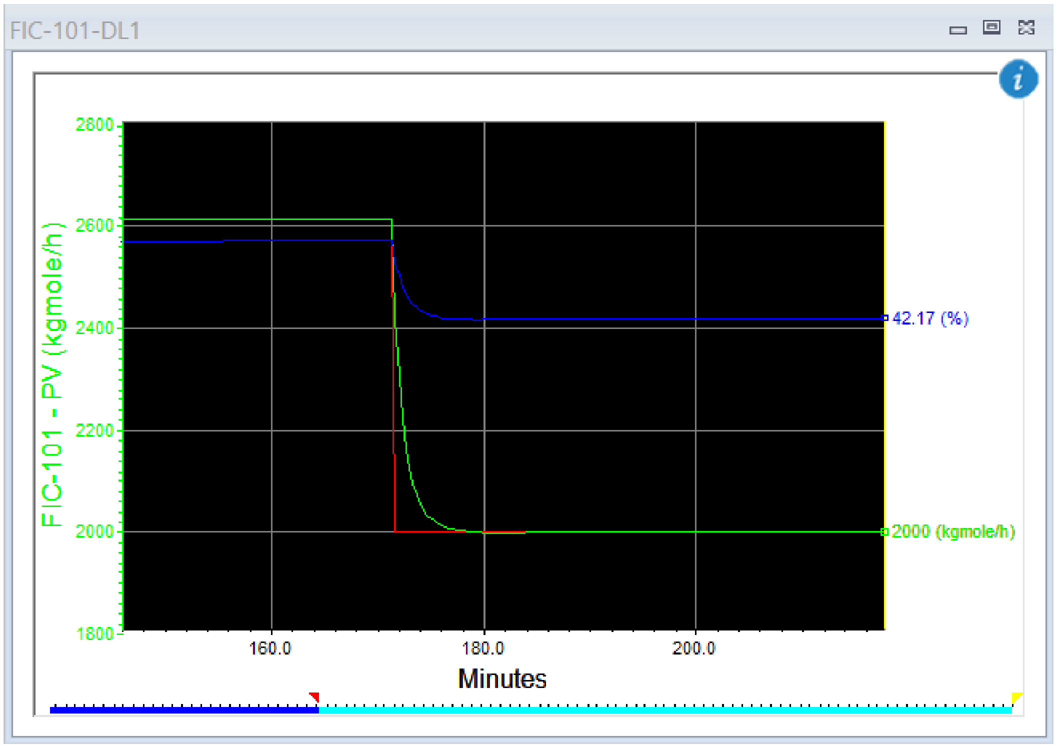


Figure 4.8 FIC-101 negative setpoint change response

6. Reboiler Liquid level controller

6.1 Hysys default controller

HYSYS allows for the automatic addition and configuration of a liquid level controller in reboiler, and performing the necessary calculations itself.

Controller	**PV**	**Output Target**	**Action**	**Kc**	**Ti**	**PV min**	**PV max**	**SP**
LIC-100	Liquid level in reboiler	VLV-100	Direct	1,80	1,42	0 %	100 %	50 %

Table 4.2 LIC-100 hysys-calculated reboiler liquid level parameters

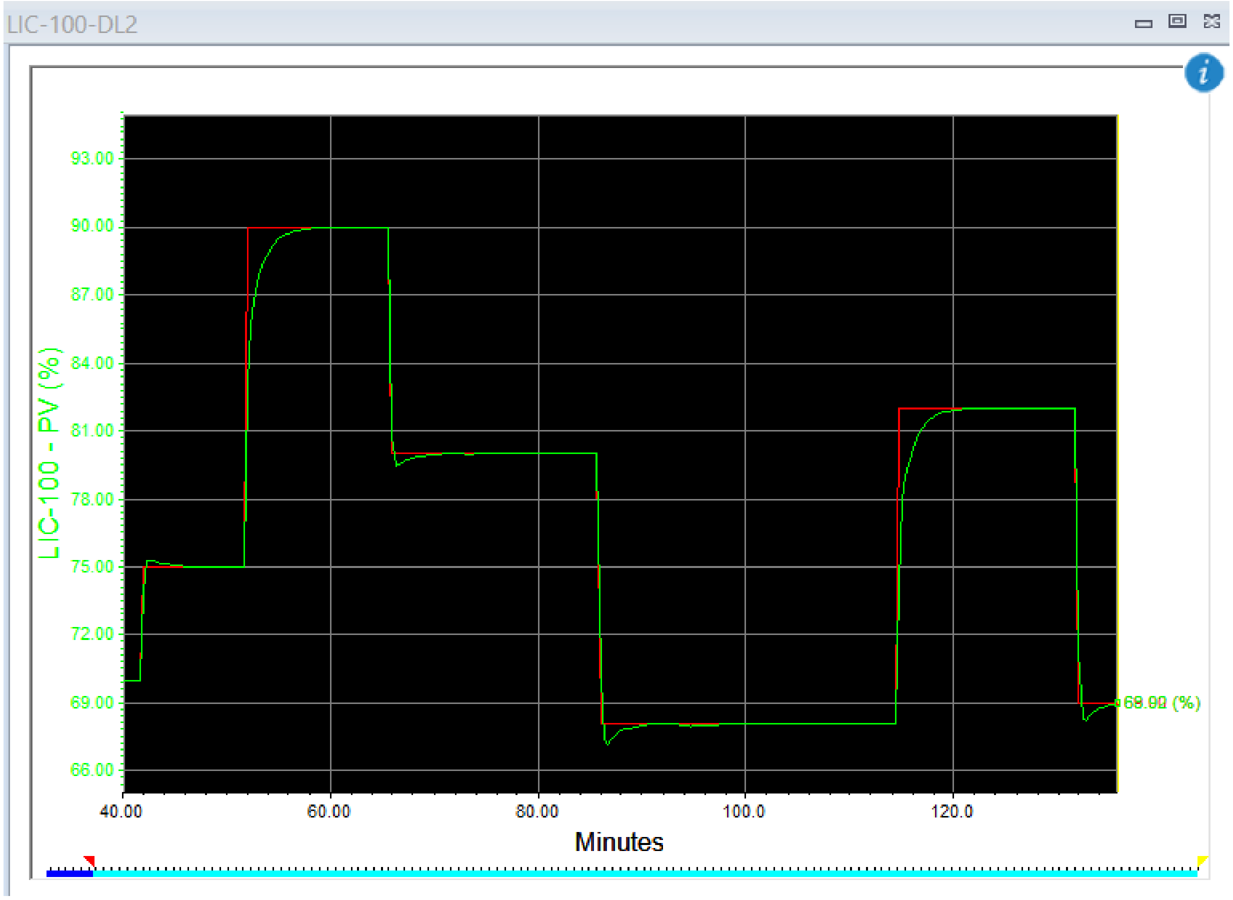


Figure 4.9 LIC-100 different setpoint changes response

6.2 reboiler liquid level controller parameters obtained with trial and error

Table 4.3 represent reboiler liquid level controller new parameters obtained through trial and error method after applying consecutive test step signals.

controller	PV	COP	Action	Kc	Ti	PV min	PV max	SP
LIC-100	Liquid level in reboiler	VLV-100	Direct	40	0,500	0 %	100 %	50 %

Table 4.3 LIC-100 obtained parameters with trial error

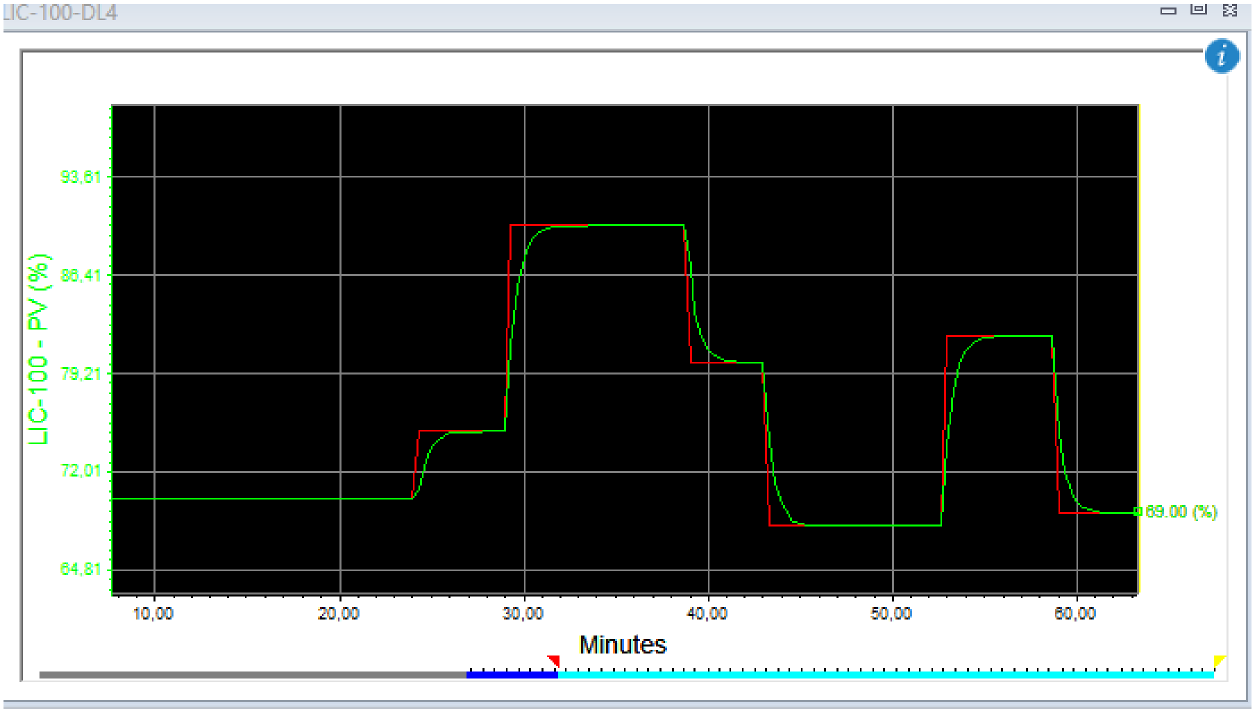


Figure 4.10 Tuned LIC-100 different setpoint changes response

6.3 comparison between default and tuned controller

Set point change	From 70 to 75		From 75 to 90		From 90 to 80		From 80 to 68	
	default	tuned	default	tuned	default	tuned	default	tuned
Over shoot %	0.3	None	None	None	0.56	None	0.7	None
Rise time min	0.58	1.05 min	9.7 min	0.68 min	0.58 min	1.41 min	0.7 min	1.34 min

Table 4.4 data comparison between default and tuned controller

Comparison result

Trial-and-Error Tuned Controller Reliable with no overshoot, but has slightly longer rise times for larger setpoint changes, the other one however has a Faster rise time for small setpoint changes but exhibits overshoot. No overshoot for larger setpoint changes, but has longer rise times in those cases.

Dynamic state simulation

The trial-and-error tuned controller focuses on stability without overshooting, whereas the Hysys-configured controller provides quicker response times with some overshoot for minor setpoint adjustments.

Conclusion

In this chapter, the integration of three controllers within Aspen HYSYS has been explored. The focus was on demonstrating their responsiveness to different set point changes and highlighting several features of the HYSYS software, while also showcasing Aspen HYSYS's capabilities in dynamic simulation, real-time monitoring

General conclusion

This paper discussed the integration of PID controllers in Aspen HYSYS. The PID controller is essential in industrial processes for maintaining accurate and stable control over variables such as temperature, pressure, and flow rate.

We presented the LPG 2 gas treating facility, which consists of three processing trains designed for efficient gas treatment. Located strategically to optimize logistical and operational efficiencies, the facility ensures high-purity LPG production through its key operating sections.

We presented various instrumentation and control engineering concepts some of which are relevant to our study and some of which are not. we described the deethanizer's operating principles and control strategies.

A steady-state model of the deethanizer 11-C-201 was developed as a precursor to dynamic modeling, in which we demonstrated identical data to actual operating conditions. This steady-state model created a reliable foundation for the dynamic simulation in which PID controller was integrated. This work enabled us to obtain a simulation model that can be used predictive and optimization purposes.

A dynamic model of the deethanizer 11-C-201 was developed to integrate a PID controller, highlighting the key differences between dynamic and steady-state simulations, particularly in terms of time dependency and the ability to reveal real-time variable changes due to operational modifications. This approach allows for a comprehensive understanding of PID controllers, as HYSYS provides a simulation environment that closely mirrors real-life PID operations. The software includes a toolbox with features commonly found in industrial settings, enhancing the realism and applicability of our simulation.

Three PID controllers were integrated into the system: two flow controllers for managing the molar flow of the entering feed streams, and one liquid level controller for the reboiler and all of their parameters were obtained through the trial and error method. HYSYS offers automatic integration of some PID controllers, including the one that controls the reboiler's liquid level, and it perform the necessary calculation to obtain the PID parameters.

After using the trial and error method, we obtained different parameters for the reboiler liquid level controller. The main difference between the controller configured by HYSYS and the one we obtained was the overshoot. The automatically integrated controller in HYSYS exhibited an overshoot of 0.7% in response to setpoint changes, whereas the controller parameters we determined resulted in no overshoot, regardless of the setpoint changes.

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Résumé

Cet travail présente une étude sur l'intégration d'un régulateur PID au sein d'un environnement de simulation, appliquée spécifiquement à un dééthaniseur. Des données réelles d'un dééthaniseur ont été utilisées pour développer une simulation réaliste dans Aspen HYSYS. Le processus a débuté par une simulation en état stable, qui a été méticuleusement comparée aux données opérationnelles réelles pour assurer sa précision. Cette comparaison a confirmé la fiabilité du modèle en état stable, formant ainsi une base solide pour une simulation dynamique ultérieure où un modèle en temps réel a été développé pour implémenter le régulateur PID.

Abstract

This work presents a study on the integration of a PID controller within a simulation environment, specifically applied to a deethanizer.

Real-world data of a deethanizer was utilized to develop a realistic simulation in Aspen HYSYS. The process started with a steady-state simulation, which was meticulously compared to actual operational data to ensure its accuracy.

This comparison verified the reliability of the steady-state model, forming a solid foundation for further dynamic simulation where a real-time model was developed to implement the PID controller.

الملخص

يقدم هذا العمل دراسة شاملة حول إدماج وحدة تحكم PID في بيئة محاكاة، ويتم تطبيقها خصيصا على فاصل الإيثان. تم استخدام البيانات الحقيقية من فاصل الإيثان لتطوير محاكاة واقعية في برنامج Aspen HYSYS . بدأت العملية بمحاكاة الحالة الثابتة ، والتي تمت مقارنتها بعناية بالبيانات التشغيلية الفعلية لضمان الدقة. أظهرت هذه المقارنة موثوقية نموذج الحالة الثابتة ، والذي قدم أساسا متينا لعمليات المحاكاة الديناميكية اللاحقة التي تم خلالها تطوير نموذج في الوقت الفعلي لدمج وحدة التحكم PID.