Simulation Studies on Vacuum Distillation Column (VDU) using the Application of AspenHysys v8.4

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Abstract
Vacuum distillation unit, VDU is one of the modern refinery unit operations that convert long chain hydrocarbon into useful and more economic reformate under reduced pressure lower than atmospheric conditions of operation (pressure and temperature inclusive). The quest to achieving a better process operation is the crux for the continue research study; to improve on the efficiency of the VDU in terms of product quality, excellent controller systems and safe operation of the equipment's and personnel. This paper presents some basic ideas on the VDU schematic flow scheme and analysis of the each unit operations using Aspen Hysys v8.4 licensed version. In this work, it was determined that eight (8) stage columns was needed to achieve a production capacity of 7500MT/h coming as s feed from the CDU at 27.58 kPa and 397.20 K, that is, the LVGO is 618.42 MT/h, while the HVGO is 5335.40 MT/h.

Keywords: *Aspen Hysys v8.4, VDU, unit operations, improvement and proper procedure*

1.0 Introduction

Distillation is one of the key processes involved in petrochemical industry (Anderson, 1998). It is an important process used in purifying chemical products prior to sale. Distillation is one of the most common separation processes employed in separating a mixture of different components based on their relative volatilities or differences in their boiling points (Anderson, 1998). Vacuum distillation is performed at reduced pressure mostly below atmospheric pressure in the distillation column making it possible for the liquid to boil at a lower temperature below its original boiling point, when under atmospheric condition. It received its feed from the crude distillation unit (CDU) and safely used to recover higher boiling points solvents. Vacuum distillation towers are usually larger in diameter compared to atmospheric distillation towers (Shukran and Abd Rahman, 2013).

Most distillation systems were designed on the basis that they operate at almost constant pressures. This presumption causes difficulty in controlling distillation towers for operators due to pressure fluctuations generated by disturbances from the process. Pressure fluctuation changes the column loads and temperature profiles and is mostly accompanied by change in relative volatilities in the column which subsequently affects fractionation performance (AIChE, 2001). Effective control of distillation operating conditions is an important step in ensuring good quality products. Proper control implementation avoids product defects arising from process disturbances. Good control system helps in safety operation of distillation column and reduces manning level.

In vacuum distillation column, pressure control is very important as it prevents the products from cracking and column flooding. Effective pressure control helps to minimize additional requirement for the control of operating temperature (AIChE, 2001).

1.1 Problem Statement

The oldest Nigerian refineries were built in late 70s, which in technological age can be considered as young operating plants. But where we have issues of improper maintenance and strictness to engineering and technological ethics, the refineries will continue to be on epileptic operations and at low capacities. To resolving these problems through indigenous input and local contents development (LCD), there is the need to use the Aspen Hysys v8.4 application to study the pressure fluctuation and stabilization of the VDU column.

1.2 Justification of the Study

Refineries overseas that are over 100 years old are still operating effectively at a reasonable and higher capacity till today. Unfortunately, the peculiar nature of the Nigerian refineries has problems of base capacity, technologies, quality manpower, crude oil supply etc. The application of indigenous technology would assist a long way to achieving the quality operations of our refineries. These technologies include using local contents input and design, operational software, quality maintenance, capacities and qualified manpower.

2.0 Background Literatures

2.1 Process overview

The furnace outlet temperatures required for atmospheric pressure distillation of the heavier fractions of crude oil are so high that thermal cracking would occur, with the resultant loss of product and equipment fouling. These materials are, therefore, distilled under vacuum, because the boiling temperature decreases with a lowering of the pressure. Distillation is carried out with absolute pressures in the tower flash zone area of 25 to 40 mmHg (Gary et al., 2007). The feed hydrocarbons should not be heated to too high temperature due to cracking reactions that take place above about 400 ^{0}C. Coke deposits on piping and equipment increase maintenance costs and reduce process unit run-time. Therefore, crude distillation bottom (residue) is further processed in a vacuum column to recover additional distillates; light and heavy vacuum gas oils as feedstock to cracking units or lube-oil processing. Three types of vacuum towers are used: dry (no steam), wet without stripping and wet with stripping. Distillation is carried out with absolute pressures in the tower flash zone area of 25 to 40 mmHg. To improve vaporization, the effective pressure is lowered even further by the addition of steam to the furnace inlet and at the bottom of the vacuum tower. The amount of stripping steam used is a function of the boiling range of the feed and the fraction vaporized as well as furnace outlet temperatures (380 – 420 ^{0}C) (VD, 2015).

2.2 The VDU Process Operations

Vacuum towers are much larger in diameter than atmospheric towers, usually 12 – 15 meters. The operating pressure is maintained by using steam ejectors and condensers. The size and number of vacuum device is determined by the vacuum needed and the quality of vapours handled, for 25 mmHg, three ejector stages are usually required. A few millimetres decrease in pressure drop between the vacuum-inducing device and the flash zone will save operating costs. In standard real refinery operation, the capacity of the presented vacuum distillation is 80 000 bbl/day (~ 4 million tons/year) with fuel consumption of about 3200 MMBtu/day (VD, 2015).

2.2 The AspenHysys Code (aspenONE)

AspenONE Engineering is a market leading suite of products focused on process engineering and optimization. In aspenONE, process modelling analysis and design tools are integrated and accessible through process simulators Aspen HYSYS and Aspen Plus copyright. Optimize process designs for energy use, capital and operating costs, and product yield through the use of activated energy, economics, and equipment design during the modelling process. Other applications of AspenHysys are: acid gas cleaning uses rigorous rate-based calculations and new property packages to deliver unprecedented accuracy and predictive results to gas absorption processes, petroleum refining layers powerful features onto the Aspen HYSYS process simulator to simplify and improve petroleum refining simulations, hydrocarbon optimisation: Aspen HYSYS is the energy industry's leading process simulation software that is used by top oil and gas producers, refineries and engineering companies for process optimization in design and operations, energy and utilities optimisation: Aspen Energy Analyser is an energy management software for performing optimal heat exchanger network design to minimize process energy etc. (AspenONE, 2016).

2.3 Process Description of VDU

The main feed to the VDU are mostly the residues from the crude distillation unit (CDU). The topped crude from the CDU bottom is pumped to the vacuum column after heated by a furnace. The heavy vacuum gas oil (HVGO) and light vacuum gas oil (LVGO) are drawn from this 8-stage column. In the fire-heater, there is need to regulate fuel flow, so as to control the temperature. In the column (VDU) there is need to control the column pressure to avoid column fracture and the cracking of the components involved. Figure 1 represents the process flow scheme (PDF) of a VDU operation. The Figure 1 is also depicting the identified control points and signal of VDU processes.

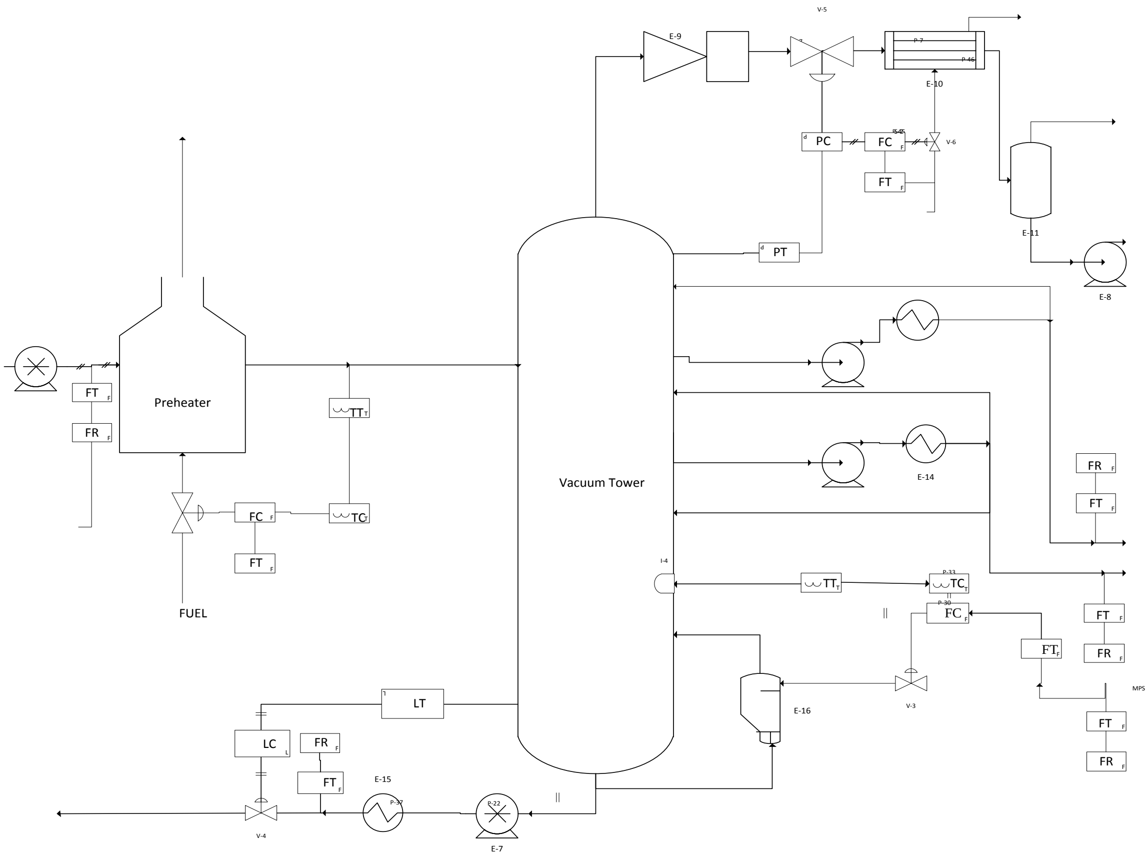

Figure 1: Probable identified control points/signal of the VDU processes (in 2015)

3.0 Materials and Methods

3.1 Materials

In this paper, the materials used are: (i) a typical VDU process flow scheme (PFS), and (ii) a licensed AspenHysys v8.4 version.

3.2 Methodology

Each of the unit operations was developed using the v8.4 version (code) to generate the complete VDU scheme in the AspenHysys version. Automatically, the materials and energy balance for each units and sub-units were generated as shown in Figure 2 below. The steps taken are as follows:

- **a)** The AspenHysys quickly accommodate the input data for the various unit operations, highlights any discrepancies and make suggestible corrections.
- **b)** Each materials and energy units were completely identified as correctly as possible.
- **c)** The operations were carried out in two-separate analysis to ascertain the capability of the AspenHysys code.
- **d)** Comparison of the results was conducted.

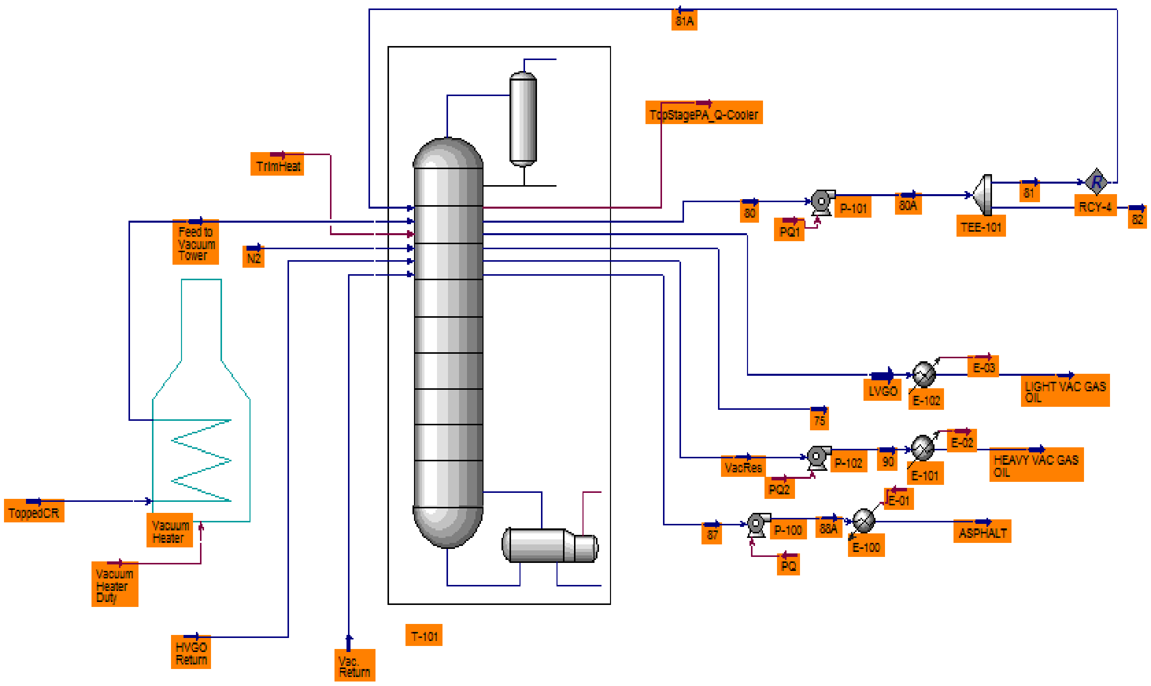

Figure 2: PFD of VDU designed using Aspen Hysys V8.4 Sources: Results from the A.Hysys v8.4 in 2015)

5.0 Discussions of Results

The results from the AspenHysys, the control analysis and possible improvement in process operation were discussed below:

5.1 The Results of the AspenHysys

The inferences drawn from the re-development of the plant is as follows:

1. Eight (8) stage columns are needed to process 7500MT/h of product from the CDU.
2. The feed must be feed to the VDU at reduced pressure of 27.58 kPa and temperature of 397.2 K as have been seen from Shukran and Abd Rahman (2013).
3. The three must important products from the VDU are light vacuum gas oil, heavy

vacuum gas oil and asphalt respectively. The re-developed results show that the flow rates of these are as follows:

Table 1: Redeveloped flow rates of LVGO and HVGO

S/No.	Process Feeds	Units	Value
a).	Light Vacuum Gas Oil (LVGO)	MT/h	– 0618.42
b).	Heavy Vacuum Gas Oil and (HVGO)	MT/h	– 5335.40
c).	Differential Feed into VGO unit	MT/h	– 1546.18
d).	(Returns) of the VGO in process	MT/h	+ 7500.00
e).	Total accumulation of VGO	MT/h	0.00

5.2 The Analysis of the Control Units and their Importance

1. Cascade controller has been used in the control of furnace to regulate the condition of the feed stream
2. Pressure controller is been was used to control the pressure of the column to avoid cracking and or explosion. This is similar to the work of Anderson, (1998)
3. The level controller is required here to avoid flooding on the process line.
4. The column temperature is also controlled by controlling the steam flow rate into the reboiler VD, (2015).

5.3 The Possible Improvement

1. To improve vapourisation, the effective pressure is lowered even further (to 10 mmHg or less) by the addition of steam to the furnace inlet and at the bottom of the vacuum tower.
2. Addition of steam to the furnace inlet increases the furnace tube velocity and minimizes coke formation in the furnace as well as decreasing the total hydrocarbon partial pressure in the vacuum tower.
3. The effective pressure (total absolute pressure – partial pressure of the steam) at the flash zone determines the fraction of the feed vaporized for a given furnace outlet temperature, so it is essential to design the fractionation tower, overhead lines, and condenser to minimize the pressure drop between the vacuum-inducing device and the flash zone. A few millimetres of decrease in pressure drop will save substantially in operating costs (Gary et al., 2007).

6.0 Conclusions

Within the limit of simulation error from the Aspen Hysys v8.4, it was determined that eight (8) stage columns was needed to achieve a production capacity of 7500MT/h coming as s feed from the CDU at a pressure of 27.58 kPa and temperature of 397.20 K, that is, the LVGO is 618.42 MT/h, while the HVGO is 5335.40 MT/h with a total return capacity of 1546.18 MT/h.

Cascade controller has been used in the control of furnace to regulate the condition of the feed stream, while pressure controller was used to control the pressure of the column to avoid cracking and or explosion; the level controller was required here to avoid flooding and the column temperature is also controlled by controlling the steam flow rate into the reboiler.

Abbreviations

CDU	-	Crude distillation column
LCD	-	Local contents development
LVGO	-	light vacuum gas oil
HVGO	-	heavy vacuum gas oil

VDU - Vacuum gas oil

Recommendations

1. An in-depth research studies should be carried out using a real life data from refinery operation and the AspenHysys code.
2. Studies should be carried out on the possibility of debottlenecking and capacity increase to an existing VDU process using AspenHysys code.

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