

HAZARD IDENTIFICATION ON FRACTIONATION COLUMN USING RULE BASED EXPERT SYSTEM

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ABSTRACT

A rule-based expert system has been developed in which the knowledge used to assist Hazard and Operability Study is divided into process-specific and process-general components. The process-specific knowledge, which consists of process operation data and the process flow sheet, has been constructed using a HYSIS process simulator. The process-general knowledge which consists of rule-based expert system is developed from simulation result obtained from HYSIS process simulator. The link between Hazard and Operability Study result documentation with data base of process operation is important, in order to analyse the causes and consequences of the whole process deviation on fractionation column. In this Hazard and Operability Study, process deviation studied are flow rate, temperature and pressure. An inference engine mechanism is developed using Visual Basic programming language, for appropriate interaction between these components in order to identify causes and consequences of deviation for each process stream. The base case study used is a fractionation column of an oleo chemical plant. The study has contributed to an improvement of hazard identification technique and proposed an algorithm by considering the whole consequences of process deviation in each stream. The algorithm is found applicable for any of process system, however the expert system developed is only limited to the application for fractionation column of oleo chemical plant.

INTRODUCTION

A new demands for better plant safety require better quality result of safety analysis, good documentation of safety data analysis as well an improvements in method and technique of safety analysis. As for the conventional method of Hazard and Operability Study, most of the result obtained is basically covered in finding the immediate causes and consequences for a particular line under consideration and the vessel connected to it. The scope of the analysis is limited to identify hazard based on their 'expertise knowledge', without critically analyse the condition of the whole operation when a specific process deviation occur. There were also lack of efforts to analyse the interactions between two lines of process deviation. Principally, this shortcoming may lead to incomplete hazard identification exercise and subsequently, may reduce the quality and reliability of the study.

This paper describes a new algorithm for finding fault propagation that will support Hazard and Operability Study by identifying relation of process deviation between two lines, which is in terms of input-output process connection. Basically, the results simulated from HYSIS process simulator has been used in the proposed method as the main base knowledge to identify other process deviations that have been affected by a particular process deviation specified.

However, the major difficulty in dealing with such proposed analysis is to handle the accumulated amount of data and knowledge in such a way that it is available to supply the correct answer at the right time as well as at the right specified condition [1]. One way of doing this would be to incorporate the knowledge used by human experts into an intelligent computer system, called an expert system. [2]

The main objective of this proposed algorithm is to support Hazard and Operability Study by integrating the experience-shallow knowledge based approach with the data-operation knowledge based, for a better qualitative result of Hazard and Operability Study.

BACKGROUND

The Principle of Conventional Hazard and Operability Study

Hazard and Operability Study or is generally known as HAZOP, is the study of systematically identifying every possible deviation from the design intent, and all possible abnormal causes and

adverse consequences that may occur in a process plant. In order to cover all possible malfunctions in the plant, the process deviations are generated by systematically applying guidewords such as MORE, LESS, NONE, REVERSE, PART OF, AS WELL AS and OTHER THAN to the process parameters. To conduct the study, a team examines the process flow sheet (usually P&I diagram). The plant is divided into sections called study nodes (usually lines or piping), and each section is studied in turn to identify what could go wrong.

Fundamental Concept of Expert System

An expert system is a computer package designed to simulate or model a human expert. It is a form of artificial intelligence and provides expert knowledge to a user through an interactive environment. A computer system that simulates the learning, memorization, reasoning, communication and action processes of a human expert in a given area of science, giving in this way a consultant that can substitute the human expert with reasonable guaranties of success. These characteristics allow expert systems to store data and knowledge, draw logical conclusions, make decisions, learn from experience and existing data, communicate with other human experts or expert systems, explain why decisions have been made and take actions as a consequence of all above. Therefore, the ultimate aim of every expert system is to substitute human expert and to improve on their performance [3].

Operability Study for Pre-Cut Fractionation Column

A conventional Hazard and Operability Study has been carried out and applied to the base case study of the Pre-Cut Fractionation Column. However, this paper is only focused on the bottom stream of the column. There are three parameters in process which have been analysed, they were flow rate, temperature and pressure. Table 1 shows part of the conventional Hazard and Operability Study result that will be discussed in the 'Result and Discussion' section later.

TABLE 1: HAZARD AND OPERABILITY STUDY RESULT OF FRACTIONATION COLUMN

Study Node	Deviation	Causes	Consequences
Feed	Less Flow	1. Valve FV 4001 partially closed 2. Partial plug or leak in pipeline	1. Quantity and quality of production will decrease 2. Fatty acid released to work area 3. Increase pressure in pipeline
Bottom	Less flow	1. Partial plug or leak in pipeline 2. Reboiler pump PP4001 fault	1. Quantity of fatty acid supplied to Light-cut Column decreased 2. Fatty acid released to work area 3. Increase pressure in pipeline

Fractionation Column of Oleo-Chemical Plant

The process used in the study is the Pre-Cut Column of Fractionation Plant in oleo chemical industry as shown in Figure 1. Due to the differences in acid distributions of the two feeds (Palm Kernel Oil Feed and Palm Stearine Feed), the pre-cut fractionation column section is operated in different modes. However, this paper is focused on the Palm Kernel Oil operation for the case study.

The dehydrated Crude fatty Acid from Palm Kernel Oil contains all fatty acid fractions from C6 to C18 plus a residue. The feed to the Fractionation Unit comes from the Hydrogenation Unit or from storage. The feed to the Pre-Cut Column first passes through the Feed Filter. The filtered feed is first heated in the feed Pre-heater, a plate and frame heat exchanger, by hot crude fatty acid from Unit 1000 and finally in the feed Heater, a shell and tube heat exchanger. The feed enters the Pre-Cut Column between the rectification and stripping section. It is then flashed into the Pre-Cut Column. The vapors, consisting of the C6, C8 and C10 fractions are condensed by direct contact in the pump around section of the column. The condensed distillate is pumped by the reflux pump and cooled by tempered water in the condenser, a plate and frame heat exchanger before being returned to the top of the pump around section. Part of the hot distillate is sent as reflux to the rectification section of the column. The net distillate is pumped to storage under level control. The bottom product are pumped by the bottoms pump and heated by hot oil, under pressure to suppress vaporization, in the reboiler, a shell and tube

heat exchanger. The net bottoms product is pumped, to the Lights Cut Column. Vacuum is maintained at the top of the column by the second stage of the Precut Column Ejector. The main product of this column is to recovered C10 and lighter cut at the distillate section as well as others heavy components at the bottom line to be separated at later stage of fractionation system.

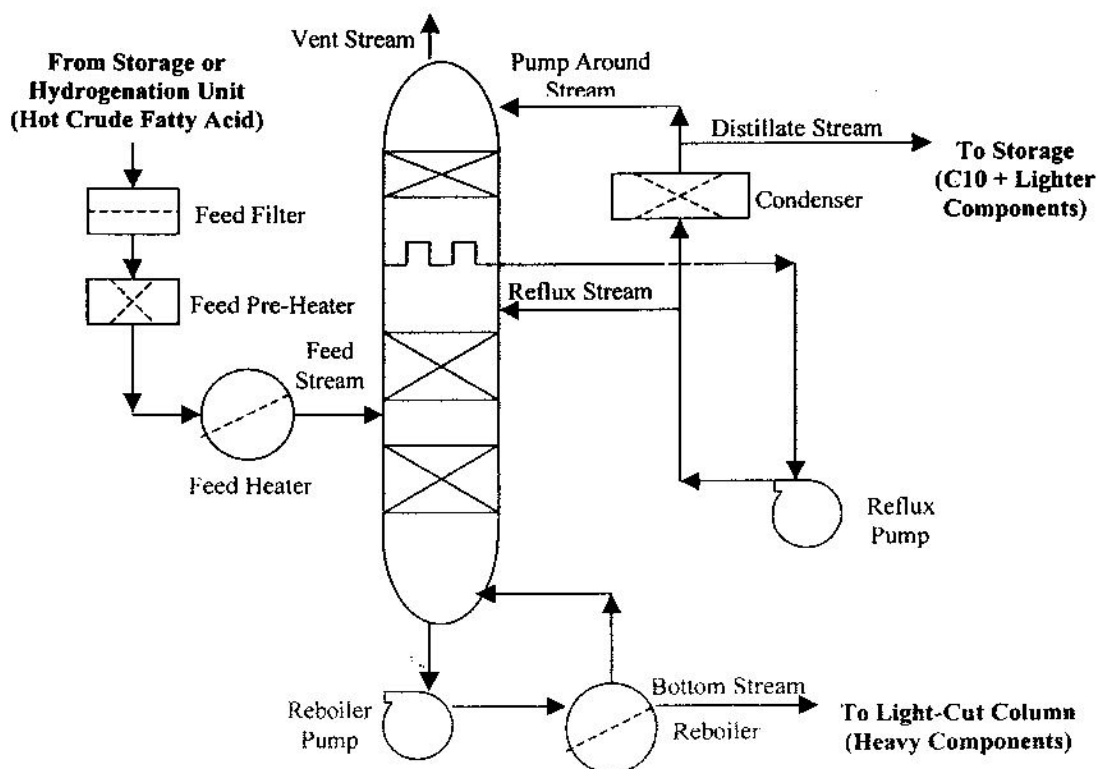


FIGURE 1: PRE-CUT COLUMN SYSTEM OF FRACTIONATION OLEO-CHEMICAL PLANT

RESEARCH METHODOLOGY

Basic Structure Algorithm of Proposed Expert System

In this paper, the algorithm of the proposed expert system consists basically of the knowledge bases and the inference engine as shown in Figure 2. The development of the expert system for Hazard and Operability Study first required the consideration of the types of knowledge required for the study, and how this types; the plant specific knowledge and the generic knowledge.

The plant specific knowledge consists of plant structure and plant operation database that has been developed using HYSYS process simulator. Based on the developed plant specific knowledge, the process deviation rule is then structured to perform the propagation of the fault for a particular process deviation specified. Generally, the significant application of the developed rule-based is to describe the condition of the entire operation parameter plant that related to the specified process parameter deviation. However, this paper concentrates on identifying a specified process deviation that are affected by a process deviation at the feed stream.

The inference engine in the expert system combines both the generic and the plant specific knowledge as to perform the proposed algorithm of operability study analysis. The user requests the expert system to carry out Hazard and Operability Study by specifying a process deviation in a process line. Previously, a key analysis stream will be identified using the rule based developed in the process generic knowledge. The key analysis will be used as a guide and it is part of the rules of fault propagation to analyse and make a decision to detect process deviation location source (process deviation feed stream or other possible causes that identified in the conventional Hazard and Operability Study). Then, each process deviation streams is studied respectively in sequence by

searching the rule based developed, using guidewords to identify the possibility of source for the process deviation that may occur. The expert system for this work is written in Visual Basic programming language. This language is excellent for expressing logic as well as performing an interactive user-friendly programming procedure structure.

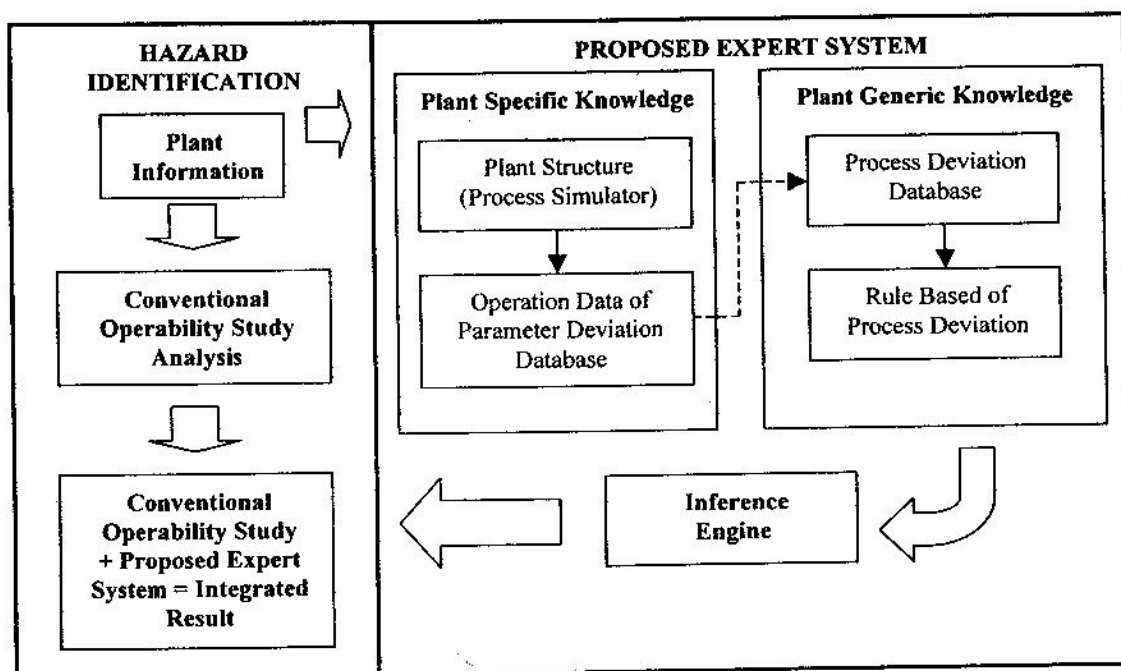


FIGURE 2: BASIC STRUCTURE OF ALGORITHM FOR EXPERT SYSTEM DEVELOPMENT

RESULTS AND DISCUSSION

Process Specific Knowledge

The plant parameter database of HYSYS simulation called Workbook, is significantly used to obtain the parameter value of the process deviation. This database will guide in developing rule-based of hazard identification for a specific deviation of a parameter process. Table 2 shows the overall results of the less flow process deviation analysis for the 'Feed Stream'.

TABLE 2: PROCESS DEVIATION DATABASE

	1	2	3	4	5	6	7	8
Parameter	Feed	Bottom	PA	To Cooler	To Tee	P/A-x	Vent	Distillate
Temperature	ND	ND	ND	ND	ND	ND	ND	ND
Pressure	ND	ND	ND	ND	ND	ND	ND	ND
Mole Flow	X	LF	ND	LF	LF	LF	LF	LF
Mass Flow	X	LF	ND	LF	LF	LF	LF	LF

Plant Generic Knowledge

The core of expert systems is the set of rules in the knowledge base in term of 'If-Then-Rules'. The set of rule-based is developed as to describe its deviation consequences criteria for each process parameter deviation specified in the Plant Specific Knowledge. An example of rule based developed is shown in the statement below.

If Bottom Stream (S2) is Less Flow, [Specified as Primary Input Stream]
 And Vent Stream (S7) is Less Flow, [Specified as Secondary Input Stream (Key Analysis)]
 Then, Feed Stream is Less Flow.

Inference Engine

The inference engine provides control strategy for processing the knowledge stored in the knowledge base as well as turn out to be as a guide tool to infer possible causes and consequences for Hazard and Operability Study. The rules is used in the inference engine as to identify the key analysis stream (S7; Vent Stream), if the 'Bottom Stream (S2)' has been specified as the primary input stream. This rules also will be used for identifying whether process deviation at feed stream will occur as the source deviation for the less flow condition at the 'Bottom Stream' or not. Table 3 indicates the result for the less flow process deviation at the 'Bottom Stream' corresponding with the seven different mode of process condition for the secondary stream (S7).

TABLE 3: PROCESS DEVIATION RESULT OF PROPOSED EXPERT SYSTEM

Process Deviation Mode at Primary Stream (S2)	Process Deviation Mode at Secondary Stream (S7)	Mode of Condition	Result for Feed Stream Condition
Less Flow	Less Flow	Mode 1	LF
	More Flow	Mode 2	LT
	Less Temperature	Mode 3	ND
	More Temperature	Mode 4	ND
	Less Pressure	Mode 5	ND
	More Pressure	Mode 6	ND
	No Deviation	Mode 7	ND

Integrated Result of Conventional Operability Study with Developed Expert System

In order to validate the algorithm proposed, an attempt has been carried out to integrate both result of developed expert system and the conventional Hazard and Operability Study. The result shown in Table 4 illustrates a simple example of a complete result analysis for the less flow condition of 'Bottom Stream'.

TABLE 4: RESULTS OF EXPERT SYSTEM ANALYSIS

Study Node	Deviation	Causes	Consequences
Bottom	Less Flow	1. Partial plug or leak in pipeline 2. Reboiler pump PP4001 fault 3. Valve FV 4001 partially closed 4. Partial plug or leak in pipeline	1. Quantity of fatty acid supplied to Light-cut Column decreased 2. Fatty acid released to work area 3. Increase pressure in pipeline

Based on the result, it is indicates that the possible causes of the less flow condition for 'Bottom Stream' has been increased quantitatively than before. This happened due to the result obtained from the expert system analysis, which indicates that the 'Feed Stream' (less flow in condition) as one of the possible cause affecting less flow at 'Bottom Stream'. Particularly, this is only true for the input analysis condition as in 'Mode 1', shown in the Table 3 previously. Although the proposed algorithm can be apply directly to the conventional result of Hazard and Operability Study without through an application of an expert system, yet the developed expert system is very significant to contribute in

improvement of proposed algorithm by taking consideration all process deviation that may occur when performing Hazard and Operability Study.

CONCLUSION

The proposed algorithm has contributed in supporting the technique of Hazard and Operability Study by increasing the efficiency of method to identify possible causes and consequences for a process deviation specified. Generally, the developed expert system is very imperative in supplying support information as well as to increase better understanding the behavior of the proposed algorithm. However, it is only developed and applicable for the fractionation column system of oleo chemical plant industry.

NOTATION

LF	Less Flow
MF	More Flow
LT	Less Temperature
MT	More Temperature
LP	Less Pressure
MP	More Pressure
ND	No Deviation
X	Process Deviation Source

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