DEVELOPMENT OF
A RULE-BASED FAULT DIAGNOSTIC ADVISORY SYSTEM
FOR PRECUT FRACTIONATION COLUMN

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DEVELOPMENT OF
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requirements for the award of the degree of
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Specially dedicated to my beloved family:

Daddy, *Mommy*, *Uncles*, *Aunties*, *Sisters* and *Brothers*

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ABSTRACT

This research presents a Fault Diagnostic Advisory (FDA) System which can be used to detect and diagnose unexpected process deviation in the operation of fatty acid precut fractionation column. The developed algorithm is expected to enhance the safety of operation in oleochemical industry. Early detection and diagnosis is useful to avoid abnormal condition that might lead to the loss of both human live and economic values. The advisory system algorithm used process history based method and presented by rule-based approach. It was developed using Borland C++ Builder 6.0 and had a user friendly interface. Plant model was simulated by using commercial simulator, HYSYS.Plant™ and verified with real plant data. Univariate Statistical Process Control technique (Individual and Moving Range (*x-MR*) chart) and Hazard and Operability (HAZOP) Study were used for the diagnostic task. The system detected and diagnosed process deviations using the saved data and the set limit. Fault occurred if the data value was out of limits. The interface of FDA System then displayed the results in the form of charts. Finally, the causes and consequences of fault were displayed. Although the scheme was developed based on data of fatty acid precut fractionation column, the algorithm of fault detection and diagnosis can be extended to other chemical process by changing the *x-MR* chart and HAZOP for each selected monitoring variables.

ABSTRAK

Penyelidikan ini menghasilkan Sistem Penasihat Diagnostik Kesilapan (FDA) untuk mengesan dan mengenal pasti sisihan proses yang tidak didugai dalam operasi turus penyulingan asid lelemak. Algoritma yang dibangunkan ini dijangka meningkatkan operasi keselamatan dalam industri oleo kimia. Pengesanan dan pengenalan pasti awal dapat membantu mengelakkan keadaan abnormal yang akan membawa kepada kemusnahan nyawa manusia dan kemerosotan nilai ekonomi. Algoritma sistem penasihat ini direka berdasarkan kaedah berasaskan sejarah proses dan disampaikan oleh sistem pakar berasaskan peraturan. Ia dibangunkan menggunakan Borland C++ Builder 6.0 dan mempunyai perantara muka pengguna yang mesra. Model loji disimulasi dengan menggunakan penyimulasi komersil HYSYS.Plant^{TM} dan disahkan dengan data logi. Univariat Kawalan Proses Statistik (Carta Tersendiri dan Had Pergerakan (*x-MR*)) dan Kajian Bahaya dan Kemampuan Operasi (HAZOP) telah digunakan untuk tugas mengenalpastian. Sistem ini telah berjaya mengesan dan mengenalpasti sisihan proses menggunakan data yang telah disimpan dan had yang telah ditentukan. Kesilapan berlaku jika nilai data tidak berada dalam had. Seterusnya antara muka Sistem FDA mempamerkan keputusan dalam bentuk carta. Akhirnya, sebab dan akibat berlakunya kesilapan dipamerkan. Walaupun, disebabkan rancangan kajian ini bergantung kepada data dari turus penyulingan asid lelemak, ia boleh diaplikasikan dalam industri kimia lain dengan mengubah carta *x-MR* dan HAZOP kepada setiap pembolehubah yang diawasi.

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LIST OF ABBREVIATIONS

x-MR	-	Individual and Moving Range
AEM	-	Abnormal Event Management
AI	-	Artificial Intelligence
API	-	Application Programming Interface
ASM	-	Abnormal Situation Management
BCB	-	Borland C++ Builder
BDE	-	Borland Database Engine
CL	-	Center Line
CVS	-	Comma Separated Values
DMP	-	Dump
ESDLC	-	Expert System Development Life Cycle
ESs	-	Expert Systems
FDD	-	Fault Detection and Diagnosis
FDA	-	Fault Diagnostic Advisory
FIC	-	Flow Indicator Controller
HAZOP	-	Hazard and Operability Study
HETP	-	Height-Equivalent Theoretical Plate
LCL	-	Lower Control Limit
LIC	-	Level Indicator Controller
ODBC	-	Open Database Connectivity
PFDD	-	Process Fault Detection and Diagnosis
PI	-	Pressure Indicator
PV	-	Process Variable

RAD	-	Rapid Application Development
S1	-	Node 1 – From Input Reboiler to Column
S2	-	Node 2 – From *Sidestream* back to Column
SPC	-	Statistical Process Control
SQL	-	Structured Query Language
TIC	-	Temperature Indicator Controller
UCL	-	Upper Control Limit
VLV	-	Valve

LIST OF SYMBOLS

x	-	Individual
$\bar{x}$	-	Mean
D	-	Constant for Moving-rang Chart
E	-	Constant for Individual Chart
MR	-	Moving Range

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Errors by operators and maintenance workers as well as equipment failures are recognized as major causes of industrial accidents (Kletz, 1990). Major chemical accidents can be attributed to explosive, i.e., catastrophic vessel failures as well as non-explosive, i.e., discharge through relief systems, pipe breaks, release of toxic and flammable materials. Concern in control and management of chemical major hazards has increased since the occurrence of major accidents: Flixborough - 1974, Seveso - 1976, Piper Alpha oil platform fire - 1988, Zeebrugge ferry disaster - 1987, Phillips petroleum fire and explosion - 1989, Challenger disaster - 1986, Esso Australia Longford explosion - 1998, Kuwait Petrochemical's refinery - 2000 and Toulouse - 2001.

In the wake of major well-publicized chemical accidents that have occurred in various parts of the world over the past two decades, many private and national companies operating in the developing countries have recognized their own vulnerability to such disastrous accidents. Nowadays, most of the companies in the chemical industry have their own safety policies. It was their responsibility to prevent and control any potential accident occurs in processing plant. Much thought have also been given to ways of reducing and minimizing consequences of the accidents, one of the methods such as building an advisory system.

An effective control is required in the process plant due to the complexity of process operation. However, effective control could not guarantee unless all information feed to control system are correct. Hence, diagnostic system is needed to detect any abnormally such as bias in measurement, sensor failure and equipments failure. Computer-based solution or a knowledge-based system for diagnostic system is needed to help ordinary field operators (Venkatasubramanian, 2003). They need information to make rapid decisions on vital questions, advising emergency services, recommending avoidance and control measures during the accidental release.

1.2 Motivation

In the past, control community has succeeded using alarm and interlock systems in removing regulatory control from hands of human operators. These systems have performed in an automated manner aided by computer due to the complicated plant operation and led to great progress in the quest for higher productivity, process safety, process efficiency and profitability.

Poor control or process disruption might lead to plant shutdown and such situations are expected to be solved by human operators with the assistance of an alarm system (Ahmad, 2004). If correcting abnormal events is fully reliance on human operators, they might tend to make erroneous decisions and take actions which make matters even worse. Literature has shown that most industrial accidents are caused by human errors and these abnormal events have significant economics, safety and environmental impacts (Lees, 1996). Hence, fault detection and diagnosis is one of the means for process safety management to aid the operator in improving the process operation.

Abnormal events could occur due to several factors such as the broad scope of the diagnostic activity that include a variety of malfunctions - process unit failures, process unit degradation, and parameter drifts and so on. Prolonged situations such as in the case of instrument failure or any rupture of pipeline could result in disasters, forced shutdowns, or at least higher operating costs from sub-optimal plant operation and it could not be avoided unless the failure is promptly detected and accomplished in time with corrective actions. Thus, it is the purpose of diagnosis to detect any fault and give advice to personnel in taking action which caused by failure of the control system. This entire activity is called Abnormal Event Management (AEM), a key component of supervisory control (Venkatasubramanian, 2003).

In the area of plant-wide control at the supervisory level, the process fault detection and diagnosis system plays a key role. Foreseeable, the important of supervisory system and the potential of computer to provide closer supervision and better information of process safety by monitoring critical parameters and, when circumstances warrant it, initialing and carrying out a safe shutdown. Due to the problems stated, that is the next grand challenges for control engineers in implementing a sophisticated system that can be able to monitor process operation.

Diagnosis consists of two different but closely related procedures. The first step is to receive response of the system through measuring device. The second step is to make a decision on the state of the system based on the sensory values. Researchers seek a way of using a computer to mimic human reasoning. There are different search techniques that can be applied to perform diagnosis based on the available process knowledge. Venkatasubramanian (2003) and his partner has summarized the basic approach in implementing diagnostic system. Knowledge engineering and advanced software tools such as expert systems can also be used for process supervision purposes.

1.3 Research Objective

The objectives of the research are as follows:

i. To develop a fault detection and diagnosis algorithm for the safety purposes in fatty acid fractionation column operation by using Univariate Statistical Process Control techniques, *x-MR* chart and Hazard and Operability (HAZOP) Study supported by rule-based approaches.

ii. To develop a fault diagnostic advisory system using Borland C++ Builder 6.0.

1.4 Scope of Research

The scope of the work consists of the following:

i. To develop Fault Diagnostic Advisory algorithm focusing on a fatty acid precut fractionation column.

ii. To develop fault detection algorithm – discriminator base on Univariate Statistical Process Control, *x-MR* chart.

iii. To diagnose common possible causes and consequences of process deviations using HAZOP study.

iv. To develop and integrate rule-based fault detection and diagnosis algorithm.

v. To verify and validate the designed fault detection and diagnosis algorithm by developing a prototype using Borland C++ Builder 6.0.

1.5 Contribution of Research

Process Hazard Analysis (PHA) has been proven to be an important tool in improving the safety of plant designs and operation. This thesis provides improvement to the existing method of fault diagnostic algorithm by introducing Fault Diagnostic Advisory (FDA) system which combines SPC and HAZOP study approaches. A case study involving precut fractionation column was used to illustrate the capability of the proposed methodology. Besides, a third party application – external database was used to improve the advisory results by giving detail information of fault position - causes and consequences.

The following publications are results from the work described in the thesis:

i. H. Y. Heng, M. W. Ali and M. Z. Kamsah. (2003). *Fault Detection and Diagnosis Using Rule-Based Support System on Fatty Acid Fractionation Colum*. International Conference on Chemical and Bioprocess Engineering (ICCBPE 2003). 103 - 108.

ii. H. Y. Heng, M. W. Ali and M. Z. Kamsah. (2003). *Fault Detection and Diagnosis Support System for Fatty Acid Fractionation Column*. 17th Symposium of Malaysian Chemical Engineers (SOMChE 2003). 767 - 772.

iii. H. Y. Heng, M. W. Ali and M. Z. Kamsah. (2004). *Fault Diagnostic Algorithm for Precut Fractionation Column*. 18th Symposium of Malaysian Chemical Engineers (SOMChE 2004). 1 - 6.

1.6 Layout of the Thesis

The thesis is divided into seven chapters. Literature review and fundamental theory of knowledge that covered in this study are discussed in Chapter II. In this chapter, x-MR chart, HAZOP study, expert system and people works on fault detection and diagnosis are elaborated. This is followed by the discussion of research methodology in Chapter III; presented the algorithm to build the fault diagnostic system. Chapter IV gives the results and discussion of the developed diagnostic system. Finally, Chapter V concludes the thesis and recommends some future works.

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