DETERMINATION OF FAILURE PROBABILITY USING FAULT TREE ANALYSIS: A HEAVIES COLUMN SYSTEM IN CHEMICAL PLANT CASE STUDY

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DECLARATION

I declare that this thesis entitled "DETERMINATION OF FAILURE PROBABILITY USING FAULT TREE ANALYSIS: A HEAVIES COLUMN SYSTEM IN CHEMICAL PLANT CASE STUDY" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have checked this report entitled "DETERMINATION OF FAILURE PROBABILITY USING FAULT TREE ANALYSIS: A HEAVIES COLUMN SYSTEM IN CHEMICAL PLANT CASE STUDY" and in my opinion, this thesis it complies the partial fulfilment for awarding the award of degree of Bachelor of Mechanical Engineering with Honours.

Signature :

Supervisor Name :

Date :

DEDICATION

To my beloved mother and father

ABSTRACT

In petrochemical production plant, there were many mechanical equipment that required a proper maintenance but this action required lot of costs. Thus, a proper risk analysis and reliability techniques will help to ensure the reliability of the petrochemical production plant and reduced maintenance costs. Therefore, fault tree analysis was being implemented in heavies column system to identify the causes for the breakdown. Moreover, the objectives for this research to identify possible failure and construct fault tree analysis (FTA) for heavies column system. All possible failure that been identified, it defined as basic event for the fault tree. Then, the basic events were linked with the logic gate to explain how the breakdown occurred. Besides that, other objectives for this research to determine the failure probabilities for each cause. Therefore, the scope for this research was focused on the development and construction of fault tree and understanding the general process of heavies column system. So, the fault tree that been constructed able to identify all possible failure and detect critical equipment in heavies column system. Through development and evaluation of fault tree, the failure probabilities for root causes were calculated. As a result, the higher the failure probabilities for equipment indicated that the equipment will be failed within prediction time. As conclusions, the fault tree was able to identify possible failure in heavies column and the fault tree that been constructed can defined how the failure of each equipment affected to the breakdown of the system. Other than that, failure probabilities that been calculated able to show the behaviour and condition of the system. Through failure probabilities, the critical equipment had been identified and it needed a predictive maintenance to increase the reliability of the system.

ABSTRAK

Untuk pengetahuan, kilang pengeluaran petrokimia memiliki banyak peralatan-peralatan mekanikal yang memerlukan penyelenggaraan yang rapi namun demikian proses tersebut memerlukan kos yang banyak. Oleh itu, analisis risiko dan teknik kebolehlangsungan yang betul dapat membantu untuk memastikan kebolehlangsungan loji pengeluaran petrokimia dan mengurangkan kos penyelenggaraan. Oleh itu, analisis pokok kesalahan telah dilaksanakan dalam sistem lajur berat untuk mengenal pasti punca kerosakan. Selain itu, objektif penyelidikan ini untuk mengenal pasti punca kegagalan dan membina analisis pokok kesalahan (FTA) untuk sistem lajur berat. Semua punca kegagalan yang telah dikenalpasti, ia ditakrifkan sebagai peristiwa asas dalam pokok kesalahan. Kemudian, peristiwa asas dikaitkan dengan pintu logik untuk menjelaskan bagaimana kerosakan berlaku. Selain itu, objektif lain untuk penyelidikan ini untuk menentukan kebarangkalian kegagalan bagi setiap punca. Oleh itu, skop penyelidikan ini tertumpu kepada pembangunan dan pembinaan pokok yang kesalahan dan memahami proses umum sistem lajur berat. Oleh yang demikian, pokok kesalahan yang dibina dapat mengenal pasti semua kemungkinan kegagalan dan mengesan peralatan kritikal dalam sistem lajur berat. Melalui pembangunan dan penilaian pokok kesalahan, kebarangkalian kegagalan untuk setiap punca telah dikira. Oleh itu, semakin tinggi kebarangkalian kegagalan untuk peralatan menunjukkan bahawa peralatan akan gagal dalam masa yang ditetapkan. Kesimpulannya, pokok kesalahan dapat mengenal pasti kemungkinan kegagalan dalam lajur berat dan pokok kesalahan yang telah dibina dapat menentukan bagaimana kegagalan setiap peralatan memberikan impak kepada kerosakan system lajur berat. Selain itu, kebarangkalian kegagalan yang dikira mampu menunjukkan keadaan system tersebut. Melalui kebarangkalian kegagalan, peralatan kritikal telah dikenalpasti dan ia memerlukan penyelenggaraan ramalan untuk meningkatkan kebolehpercayaan sistem.

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LIST OF ABBEREVIATIONS

BDD	Binary Decision Diagram
BDO	Butanediol
FMEA	Failure Mode and Effect Analysis
FTA	Fault Tree Analysis
GBL	Gamma-Butyrolactone
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
MTBF	Mean Time Between Failure
P & ID	Piping and Instrumentation Diagram
PSM	Projek Sarjana Muda

CHAPTER 1

INTRODUCTION

1.1. Background

Petrochemical plant was one of industrial process plant that produce or manufacture various petrochemical products in large quantities. In order to produced petrochemical products in large quantities, it used heavies column system that have special equipment, units and technologies. A heavies column system usually used in distillation of liquid mixture or oil refinery to separate liquid mixture based on its volatility. So, the heavies column system was essential item in chemical plant industry to produce petrochemical products in large quantities.

Nowadays, chemical power plant became more complex as their column system usually operated at very extreme condition. This extreme condition reduced the life cycle of equipment thus it caused the failure of equipment. Industrial statistic showed that the cases of major failure and accident in the chemical power plant system was very seldom but the failure for every subunit and equipment for each column system was common (Mohammad Rizza Othman, 2007). The major problem was unable to predict the possible failures for the heavies column system. Therefore, to avoid serious consequence from happening, a systematic approach was needed to predict the failure probability of system to prevent the breakdown. So, fault tree analysis (FTA) was introduced to predict and determine the possible failure for each component in heavies column system.

A heavies columns system was the main unit operations in chemical plant industry. They usually found in tall structures with many process included such as ion exchange, purification, regeneration, filtration and distillation. Recovery process occurred in the heavies column system as shown in Figure 1.1. Raw material such as crude oil had to undergo refining process in distillation and heavies removal column system. Due to the various process that involved in the heavies column system, all the components and parts

need to be maintain regularly. Therefore, with fault tree analysis, preventative maintenance will help to maintain the health of heavies column system over time.

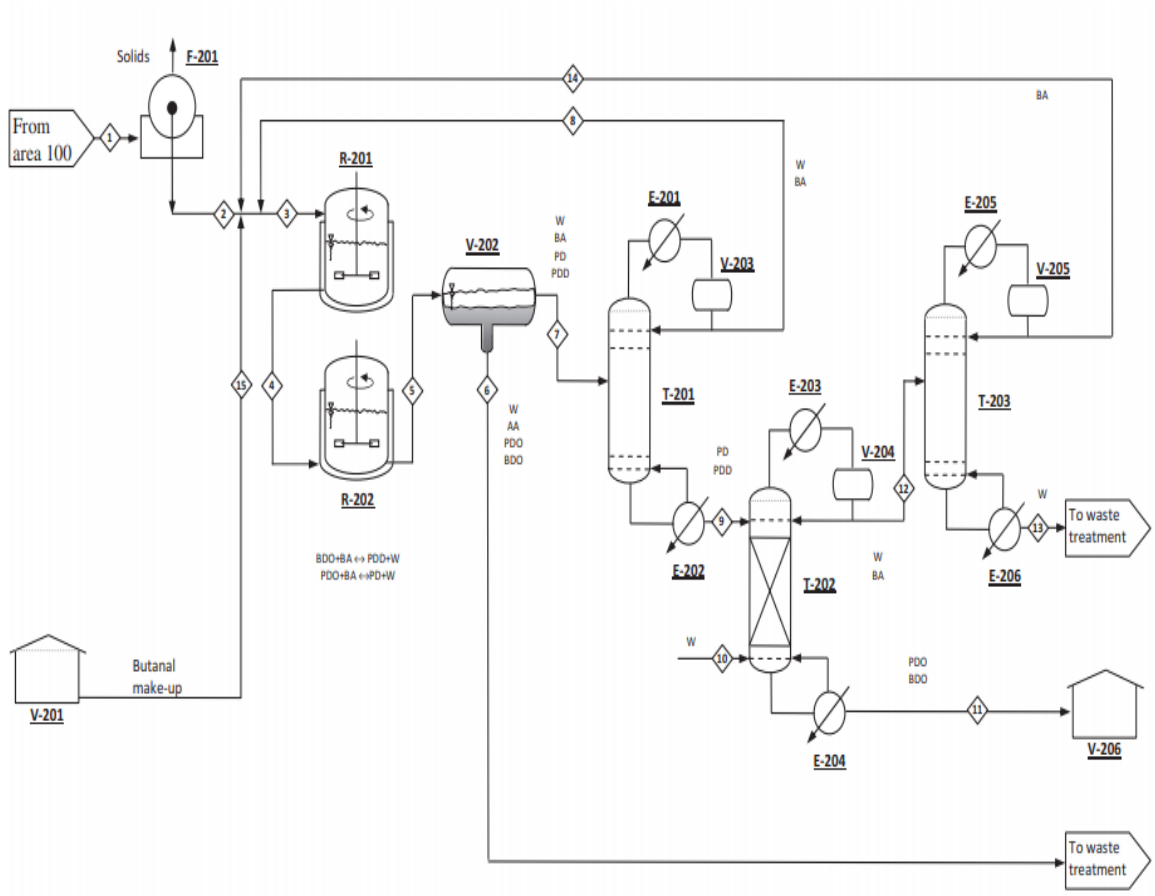

Figure 1.1 A recovery process occurred in the heavies column system (Apostolis A. Koutinas, 2015)

The ability to predict the reliability of the system was important in engineering design. Fault tree analysis was one of the well-established methods and widely used to determine the reliability of the system. Starting with the undesired event, fault tree analysis can make a graphical representation of the relation between the root cause and the failure event at different level (G Criestea, 2017).

Besides, Alaa Daher has stated in his research that the maintenance, work repair and reconstruction of column systems are very expensive and time consuming (Alaa Daher, 2019). So, it required the reliability techniques to identify the failure modes of the system and calculated the failure probabilities. For this research, fault tree analysis will be developed to find and relate the failure of the equipment that can lead to the failure of heavies column system.

1.2. Problem Statement

Heavies column system was the most important and critical system in petrochemical industry. Thus, petrochemical power plant depended on the capacity of the column to work properly. The petrochemical power plant consisted many columns such as distillation column and heavies column. Dyment stated that heavies column was one of difficult design and operational changes (Dyment, 2020). Thus, it was difficult task to control and measure the risk and failure for heavies column system. Therefore, the main problem in maintaining the heavies column system was unable to forecast when the heavies column system was at high risk and breakdown. So, it caused many maintenance work, cost and time to repair the system again.

Thus, for this research, fault tree analysis (FTA) was being implemented to describe how the failure of the component leaded to the breakdown of the system. Fault tree analysis was important reliability method that aimed to identify the possible failure and create graphical aid about how the breakdown of the system occurred. Moreover, Enno Ruijters stated in his research, FTA was quantitative analysis that can measure the failure probabilities for the system (Enno Ruijters, 2015). With fault tree analysis (FTA), the reliability of the system can be measured and critical unit in the system can be identified. Therefore, fault tree analysis (FTA) was a good risk assessment technique that can be implemented in petrochemical production plant. FTA helped to ensure all critical assets and equipment in heavies column system operated in safe condition other than to increase the reliability of the system.

1.3 Objectives

For this research, there were two objectives that been listed to solve the main issues, the failure of heavies column system. The objectives of this research were as below:

I. To identify the possible failure and construct a fault tree for heavies column system.
II. To determine the failure probability value for each possible root cause.

1.4. Scopes

Scope for this research were to understanding the general process and production of heavies column system. This knowledge was required because to construct a good fault tree analysis. Firstly, the system to be studied should be described by defined the function and identification of the system interfaces such as electrical and mechanical interfaces (IEC, 2006). Thus, the required information for this research were the function of heavies column system, identification of mechanical equipment and summary design of the system. Moreover, fault tree analysis mainly focused on the failure of the equipment in the heavies column system and how the failure of component can lead to the failure of the heavies column system.

Besides that, the research will be focused on the development and implementation of fault tree analysis in the heavies column system. For this research, the objective to develop fault tree was to identify the causes or combination of causes that lead to the failure of heavies column system. From the fault tree, the critical component or equipment in the heavies column system can be identify and calculation of failure probabilities to know the reliability of the whole system.

1.5. Project Timeline

Planning and managing during completing the research are very important to ensure the project can run smoothly and also it can be complete with the time given. For this section, a overview of methodology is described to achieve the main objective of this project. Figure 1.2 showed the flowchart of the project.

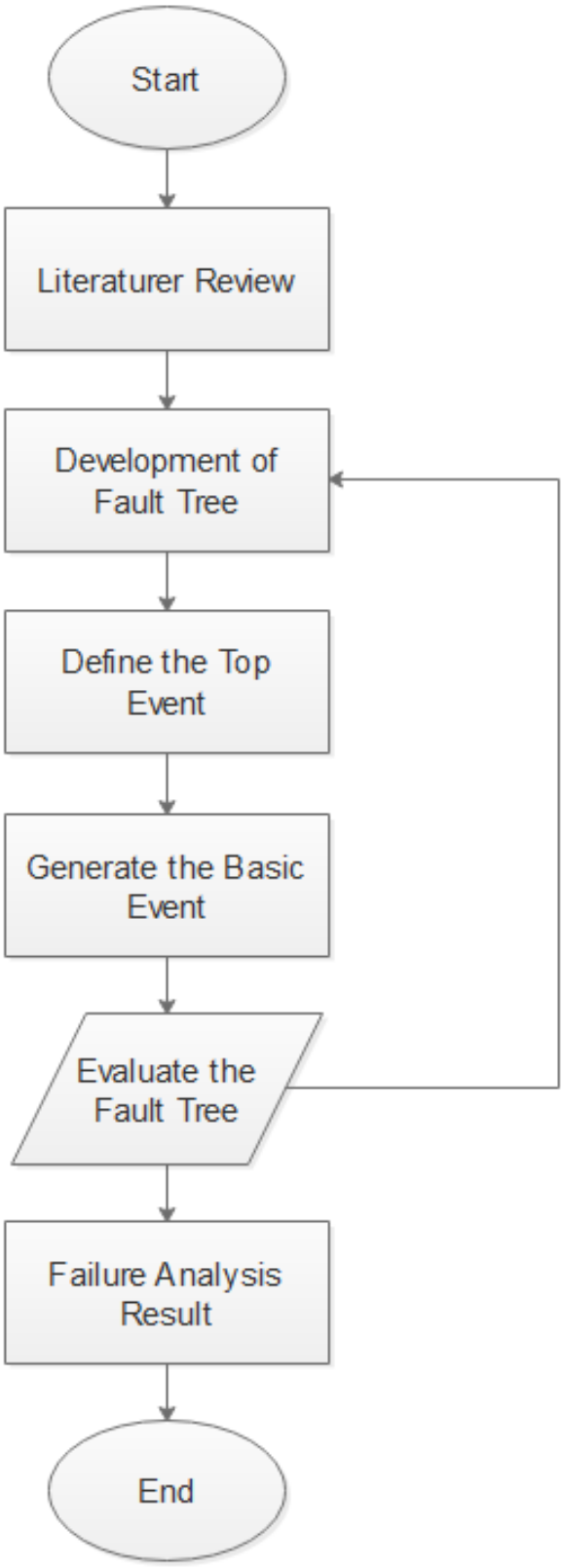

Figure 1.2 Flowchart of the project

From Figure 1.2, the flowchart showed the general methodology used in this project to achieve the objectives. The project started with gathering information and knowledge by doing literature review. The literature review mainly focused with discover the knowledge and information about the fault tree analysis (FTA). This step was important because the research and experimental test from another author can guide to understand about the concept, advantages, and limitation of fault tree analysis. Thus, it can improve the fault tree method so the failure probability can be calculated accurately.

Next, the development of fault tree analysis (FTA). For this step, international standard IEC 61025 that explain about the fault tree analysis (FTA) was used as a guideline to create and develop the fault tree analysis for heavies column system. By using the IEC 61025 as references to construct the fault tree for heavies column system, it can ensure the fault tree that been developed during this research follow the international standard. Thus, it can ensure all the analyst to understand the fault tree that had been developed.

Besides that, the first step to construct the fault tree was the analyst must define the top event. Top event defined as the main failure or undesired event for the system. For this research, the top event of the fault tree was the breakdown of heavies column system. Other than that, the analyst must have a detailed knowledge about the process occurred in the system, the design of the system and the procedure for each equipment. These knowledges were required in order to developed the fault tree. So, the top event can be elaborate to detect the root causes of the failure.

Next, generating the basic event was the process to identify the causes that lead to the top event. The usage of logic gate and Boolean theorem was important in this step to make the fault tree diagram very clear. After that, the fault tree will be evaluated to make sure all the possible failure or root causes were being defined properly. Then, the data were collected in order to calculated the failure probability of the top event.

Lastly, failure analysis result consists evaluation of the data which mean the raw data were converted to the probabilities value for each basic event. The failure probabilities of basic event were calculated until the failure probability of top event. Then, the failure analysis results will be documented to propose and plan preventative action for the failure also plan the maintenance work for the system.

1.5.1. Project Milestone

Project's Gantt Chart were shown in Table 1.1 and Table 1.2 respectively. The project started by gathering information by doing literature review on the fault tree as a method to detect the failure on heavies column system. After that, the construction of fault tree must be done as it was the first step in order to achieve the objectives of this study. After the data had been collected, the data will be converted and calculated the failure probability of the failure. Then, the failure will be analysed to get the result of this study. Thus, the failure can be ranked based on the occurrences to fault. Lastly, the report for the tests was written thoroughly to fulfil the requirement of the study.

Table 1.1 The Gantt Chart for PSM 1

Task	PSM 1													
	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature Review														
Project Planning														
Construction of Fault Tree														
Report Submission														
PSM Seminar														

Table 1.2 The Gantt Chart for PSM 2

Task	PSM 2													
	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Real Data Calculation														
Failure Analysis and Results														
Report Submission														
PSM Seminar														

CHAPTER 2

LITERATURE REVIEW

2.1. Heavies Column System

Heavies column system was a system that usually consisted of one single column, several pumps, condenser, boiler and heat exchangers. Due to many equipment involved during the process, the maintenance work should be done regularly to avoid any of the components in bad condition and not suitable to run. Therefore, the estimation of failure for the components or equipment cannot be estimated correctly. Alan Williams in his research, stated in other to maintain the performance and condition of heavies column system, it is essential to develop a tool that can monitor and estimate the reliability for the whole systems (Alan Williams, 2002). Due to the large scale and complex, sometimes there were several unit or equipment that overlooked and it can cause a failure for the components.

2.2. Fault Tree Analysis

Monitoring the condition of complex system such as heavies column system involved many human expertise and their experience to monitor and diagnose the condition of the system over the time. So, fault tree analysis was introduced to help the human to analyze the behaviour of the system or system abnormalities. Therefore, for this study fault tree analysis was being proposed to calculate the failure probability for heavies column system and minimize the risk of the failure over the time.

Besides that, Hu stated fault tree analysis is systematic approach to conduct qualitative and quantitative analyses of safety and reliability of a system (Hu, 2019). In addition, Kabir also mentioned that fault tree analysis was deductive analysis started with definition of top event and fault tree functions downwards to determine the root causes of the top event of fault tree (Kabir, 2017). From both studies, the fault tree analysis can be described as a top-down approach method to detect failure and root causes for the failure.

Starting with the undesirable events that been called as top event and then it go down to detect causes of the failure that been called as basic events.

The determination of top event, intermediate events and basic events were based on the taxonomy hierarchy as shown in Figure 2.1. The taxonomy is a systematic classification of items, equipment and system based on several factors such as location, use and subdivision (ISO, 2016). From Figure 2.1, the top event for this analysis was the failure of heavies column system which at level 5 (section/ system) from the taxonomy. While, the intermediate events for this analysis were in level 6 (equipment class/ unit). This class (level 6) for typical equipment units used in the system such as compressors, motors, heat exchanger and pump. For this analysis, the fault tree analysis covered two taxonomic level only to calculate the failure probability for the system. Moreover, the level 6 (equipment/ class unit) from taxonomy hierarchy (ISO, 2016), mainly focused on the mechanical equipment involved in the heavies column system. Therefore, this study aimed to find the causes or relationships of the equipment in the heavies column system, if one of the equipment failed can caused the failure of the system.

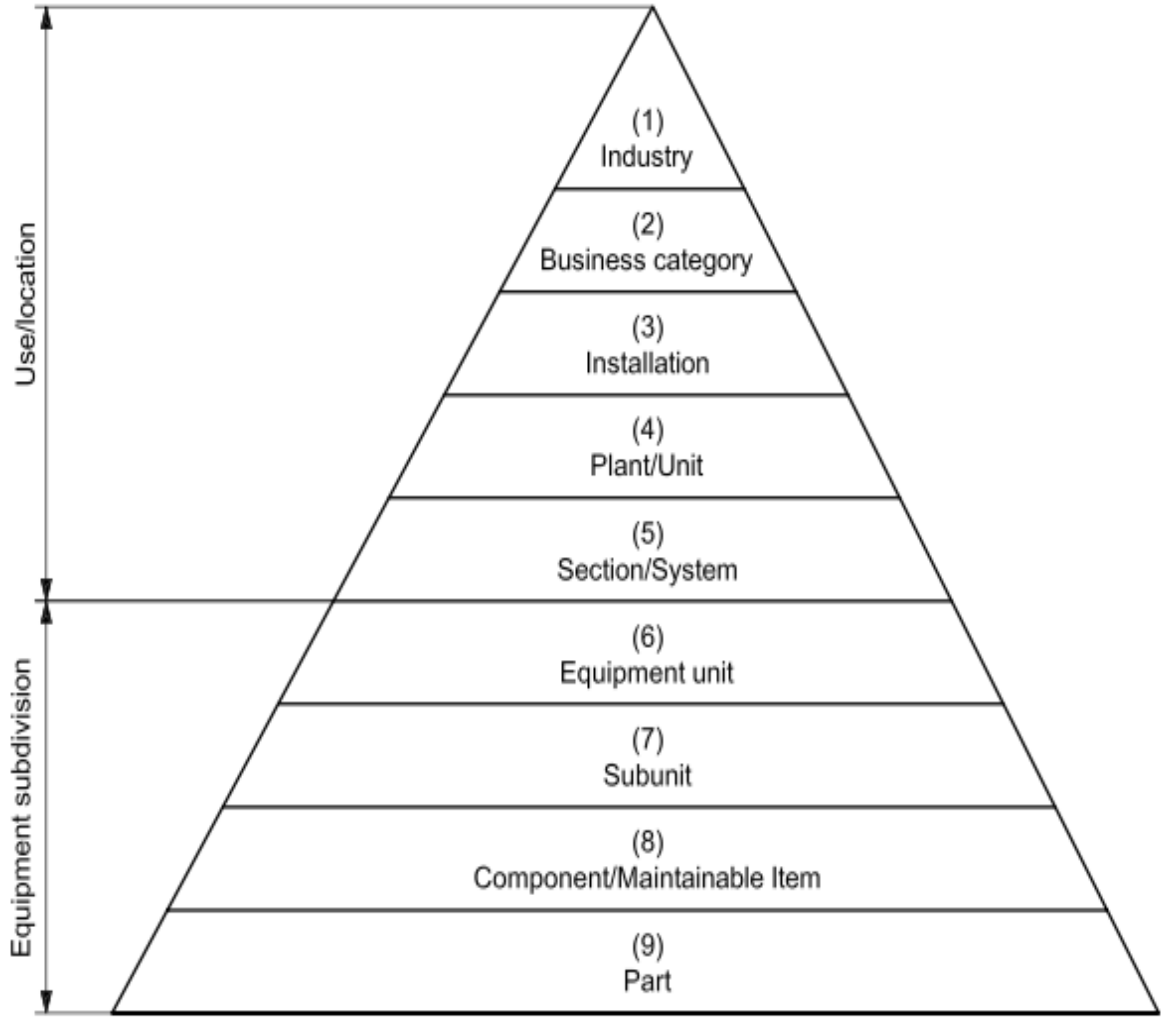

Figure 2.1 Taxonomy hierarchy (ISO, 2016)

Besides that, fault tree analysis widely used in risk analysis assessment for a system. The fault tree was being used to analyze the system abnormalities and faults. On the other hand, it can be used to detect the root causes (basic event) and calculate the probabilities value of the failure for each cause. Therefore, fault tree analysis can help engineers to provide efficient solution to prevent the failure and maintain the health of the system as fault tree can create specific combination between the top event and basic events along the value of fault probability correctly.

2.3. Fault Tree Symbology

There were two basic types of fault tree diagram which are events and logic gates. These symbols help to understand the diagram and flow of the failure and its consequences.