PERFORMANCE EVALUATION MODELING OF PRE-TREATMENT UNIT IN GAS PROCESSING PLANT

by

Mohamad Rozi Bin Sulaiman (10721)

A project dissertation submitted in partial fulfillment of

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31750 Tronoh

CERTIFICATION OF APPROVAL

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Approved by,

(Dr Ainul Akmar Mokhtar)

UNIVERSITI TEKNOLOGI PETRONAS
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMAD ROZI BIN SULAIMAN

Date

ABSTRACT

This paper presents a report for Final Year Project (FYP). The title of the research project is Performance Evaluation Modeling of Pre-Treatment Unit (PTU) in Gas Processing Plant which under manufacturing from mechanical field. The project is conducted at one of Gas Processing Plant which is Pre-treatment Unit (PTU). The project started with identification of critical component for PTU, construction of reliability block diagram (RBD) and reliability analysis based on RBD model. During the completion of the project, the researcher has been assisted by reliability engineer from PETRONAS Gas Berhad in verifying the RBD model. The outcome of this project is a model of reliability that could be used by plant management to evaluate the current reliability of the PTU. Besides, this research can analyze whether that equipment has achieved target plant reliability and identify the sub-component that reduces the overall reliability of the system. This paper includes introduction, literature review, methodology, result and discussion and conclusion. The report will include introduction, literature review and theory, methodology, result and discussion, conclusion and recommendation and reference.

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In the name of Allah, the Most Gracious, the Most Merciful. Praise to Him the Almighty that in his will and given strength, the author managed to complete this final year project within the time required.

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LIST OF ABBREVIATION

AGRU	Acid Gas Removal Unit
DHU	Dehydration Unit
GPP	Gas Processing Plant
LTSU	Low Temperature Separation Unit
MTBF	Mean Time before Failure
MTTF	Mean Time to Failure
MTTR	Mean Time to Repair
PGB	PETRONAS Gas Berhad
PFD	Process Flow Diagram
P&ID	Piping and Instrumentation Diagram
PRU	Product Recovery Unit
PTU	Pretreatment Unit
RBD	Reliability Block Diagram
TCOT	Terengganu Crude Oil Terminal

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Background of Study

The equipment effectiveness is a vital factor for a productivity improvement. Sometimes, equipment breakdown occur during the production hour which causes shutdowns, delay production, unplanned repairs, cause profit loss and reduce equipment effectiveness (Stephens, 2004). Basically this project will study on the system reliability of the equipment. Reliability of a system can be defined as the ability of a system to perform its intended function during expected life period. This means that the equipment should be able to perform its task with estimated capacity (Stephens, 2004). In order to optimize the system reliability and improve equipment efficiency the study on equipment reliability is needed. One way in obtaining system reliability of the equipment is by constructing reliability block diagram (RBD). The used of RBD method can help in determine optimum scenario for equipment to function and thus increase system efficiency. Besides, the analysis using RBD can gives other important data such as maintainability and availability.

This project will focus on construction of reliability modeling of PTU in the Gas Processing Plant (GPP). Basically, GPP consist of several units which are Product Recovery Unit (PRU), Low Temperature Separation Unit (LTSU), Pre-treatment Unit (PTU), Acid Gas Removal Unit (AGRU), and Dehydration Unit (DHU). In general, GPP is used to process natural gas in order to obtain methane, ethane, propane, and butane. Usually, the gas will contain significant quantities of water and other impurities. The gas will go through PTU, AGRU and DHU in GPP to filter out the unwanted component in the gas. Please refer to figure 1.1 for the flow diagram of GPP. The PTU is located at the first stage of the process.

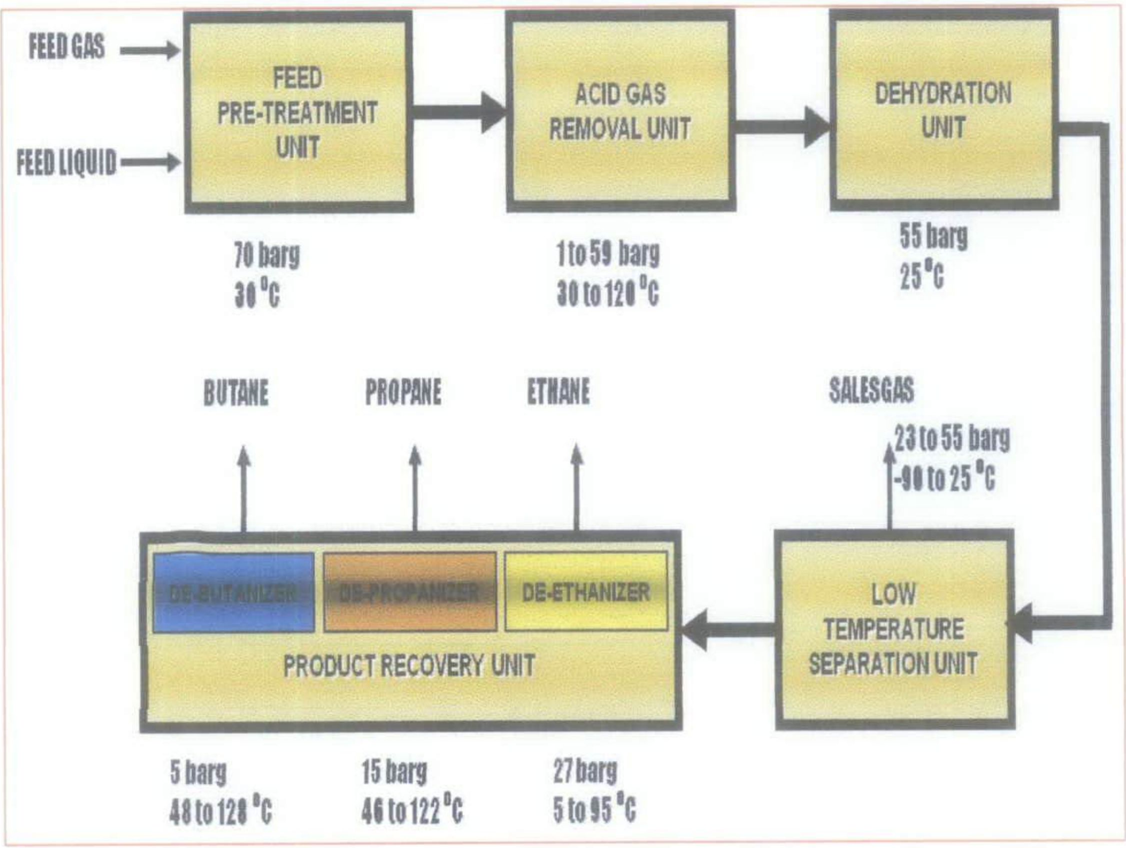


Figure 1.1: Flow Diagram for GPP (PETRONAS Gas Mechanical Note)

1.2 Problem Statement

Presently in PETRONAS Gas Berhad (PGB), the planned production output is lesser than target due to equipment breakdown or failure and other problem that reduces the effectiveness of equipment. In order to increase production and profitability, it is necessary to have better maintenance in combination with structured reliability engineering. For this purpose, proper maintenance strategies and production planning is needed ensure that equipment can be fully optimized. Before such decision to improve the performance of equipment can be made, it is essential to have a proper study on reliability the equipment. This research study can be done by using reliability block diagram model.

1.3 Objective of Study

1. Determine the importance systems and components that have potential to cause failure or system breakdown to PTU.
2. Develop block diagram of PTU that could be used as a guidance to reduce PTU failure.
3. Utilize RBD modeling to conduct a what-if analysis in order to improve system reliability.

1.4 Relevancy of Project

The performance of a system often been reduced by system failure due to ineffective equipment. The ineffective equipment can result to production shutdown, unplanned repair, delay of production and also profit loss. One way of improving the efficiency of the equipment is by improving system maintainability and availability. Throughout the research project, the construction of reliability block diagram is useful in analyze the reliability and availability of complex system. The result from this research can be used as a reference in conducting any task or activities in order to improve equipment efficiency.

1.5 Feasibility of Project

This project by far is a basic fundamental study in reliability engineering. The construction of reliability block diagram is a basic step in order to get system reliability of equipment. The project is feasible to be completed within the scope of study and time frame. Besides, this project has the potential to be developed into a more complicated and diverse project for further studies however that may requires more knowledge and time duration.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.0 LITERATURE REVIEW AND THEORY

2.1 Reliability Analysis

Reliability can be defined as the probability that a system will perform properly for a specified period of time under a given set of operating conditions (Carazas et al, 2010). Basically, reliability is concerned with avoiding events called failures. Reliability is calculated based on lack of failures. Failure is a deterioting event that makes equipment cannot be used or produced during a designated time interval (Barringer, 1996). Failures include stoppage due malfunction, stop of component function and unexpected occurrence that interrupts routine operation of system.

The reliability analysis is based on the time to failure data analysis. The formula for calculating the reliability of a component with constant failure rate (λ) for an operating period (t) is:

$$R(t) = \exp(-\lambda t)$$

Where λ is same as reciprocal of mean time between failure (MTBF). Since most components considered for analysis are repairable, the term MTBF is used to indicate the cycle time between failures (Yim et al, 1998).

In describing reliability phenomena, random failures that represented by the exponential probability function are mostly used. Random failures are defined by the assumption that the rate of failure of system is independent of its age and other characteristics of its operating failure. For a complex system, the failure modes are not usually random. So, the reliability of complex system cannot be modeled by an exponential reliability distribution. Usually, the equipment's initial performance depends on commissioning, operational procedures and environmental conditions that can induce the occurrence of early failure modes (Carazas et al, 2010)

When the phenomena of early failures and aging effects are presented, the reliability of a device or system becomes a strong function of its age. The Weibull probability distribution is one of the most widely used distributions in reliability calculations involving time related failures. Through the appropriate choice of parameters a variety of failure rate behaviors can be modeled, including constant failure rate. The reliability of weibull distribution can be represented by following equation (Carazas et al, 2010).

$$R(t) = e^{-(\frac{t}{\eta})^{\beta}}$$

Where:

R (t)	reliability at time t
T	time period (hour)
β	Weibull distribution shape parameter
η	Weibull distribution characteristic life (hour)

2.2 Need for Assessing Reliability

Critical equipment plays a vital role to industry. Failure of critical equipment can cause major profit loss because equipment will stop to function. One of the reasons that make critical equipment in trouble is due to lack of redundancy. Lack of redundancy for critical equipment occurs because of the high cost of very reliable equipment and also lack of space for installation of redundant (Barringer, 1996). Reliability analysis can provides a means for systematically improving reliability throughout the equipment life cycle. Reliability analysis is used in setting goals, evaluating, comparing, and improving directed toward continuous reliability improvement. (Dhudsia, 1992).

The reliability improvement consists of five basics step. The steps are:

- Establish reliability goals and requirements for equipment
- Apply reliability engineering or improvement activities, as needed
- Conduct an evaluation of the equipment or equipment design
- Compare the results of the evaluation to the goals and requirements and make a decision for the next step
- Identify problems and root causes

According to (Heizer & Render, 2011), reliability of equipment can be increased by improving individual component and also provide redundancy.

2.3 Data for Evaluating Reliability

Failure rate data can be collected directly from the equipment. If the data from equipment is not available, the failure data can be get from many sources. One of the sources is OREDA handbook. Data from OREDA has been recommended to asses the failure rate of equipment. For equipment classes covered by OREDA this has been considered the most relevant database as it is based on data from the oil and gas industry (Funnemark et al, 2006).

2.4 Pre-Treatment Unit

Gas pre-treatment unit is used for gas extraction, pressuring, dehydration and filtering purpose (Klinkkenbijl, 1999). Pre-treatment unit in gas processing plant usually consist of an acid removal step, dehumidifier, mercury removal step and gas liquid separator. Refer to table 2.1 for general components of pre-treatment unit.

Table 2.1: General Components of Pre-treatment Unit

COMPONENTS	FUNCTIONS
Dehumidifier	Remove moisture in the sample gases to prevent dew condensation inside automatic analyzer
Gas-Liquid Separator	Separate condensate from sample gas in the process of dehumidification
Acid Gas Removal Step	Remove carbon dioxide (CO_2) and sulphur compound
Mercury Removal Unit	Remove mercury compound
Filter	Protect analyzer, flow meter and sampling pump from dust. Filter must be replaced on a periodic basis and whenever clogging is found by visual inspection.

2.4.1 The importance of PTU

Natural gas generally requires removal of hydrogen sulfide (H_2S), carbon dioxide (CO_2), and carbonyl sulfide (COS), organic sulphur compounds, mercury and water in order to meet product specifications, avoid blockages and to prevent damage to process equipment (Klinkkenbijl, 1999). Refer to figure 2.1 for example of Pre-treatment section.

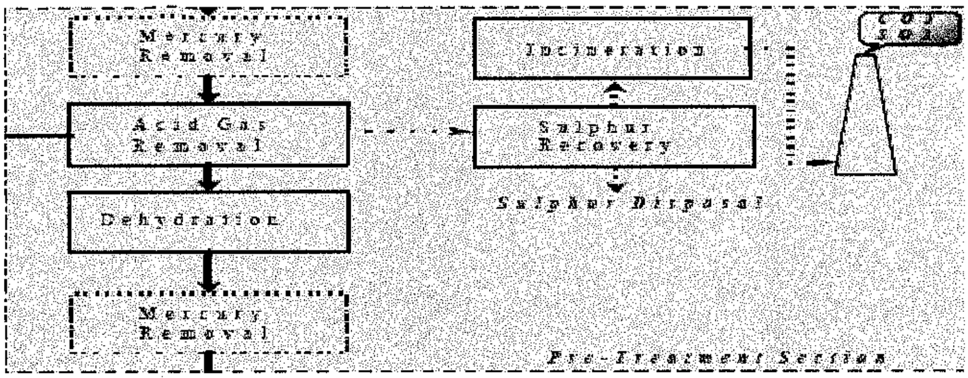


Figure 2.1: Pre-treatment (Gas Pretreatment and their Impact on Liquefaction Processes)

2.5 Studies to Asses Data of Equipment

Based on previous research (Michelassi & Monaci, 2008), there is certain study needed in order to collect useful data of a complex system which includes:

1. Reliability Data Collection
2. Maintainability Analysis

2.5.1 Reliability Data Collection

Reliability data collection is important in order to gather reliability information. For this step, all related documentation and Plant and Instrument Diagrams (P&IDs) were analyzed so that the critical components which can cause failure to system can be identified. It is important to analyze every component because failure of such components can result in production loss. The data collection also required collecting of data for life time and repair time to estimate failure time and time needed for repair. Besides, for maintenance improvement purpose there is certain data required which includes operating record, previous maintenance strategy, MTTF and mean time to repair (MTTR).

2.5.2 Maintainability Analysis

Maintainability is defined as the probability of performing a successful repair action within a given time (ReliaSoft Corporation) Maintainability actually measures the speed and ease of a system to be restored to operational condition after a breakdown happens. This analysis similar to system reliability analysis but this analysis only gives interest to time-to-repair rather than time-to-failure. This step is important because it can identify the tasks and the time required to carry out corrective maintenance. For example, if it is said that a particular component has 90% maintainability for one hour, this means that there is a 90% probability that the component will be repaired within an hour (ReliaSoft Corporation) . Maintainability analysis can be combined with system reliability analysis to obtain performance of a system such as availability, uptime and downtime so that it is easier to make decisions about the design or operation of a repairable system.

2.6 Functional Block Diagram

A functional block diagram is used to show how the equipment functions. A block diagram can be used to create a simple reliability model because it's help to understand how equipment work and what cause equipment to fail. The creation of functional block diagram can help in understanding the function of all PTU components for this research.

2.7 Construction of Reliability Block Diagram

There are many methods available to evaluate reliability of engineering system. The two widely used methods are block diagram and Markov processes (Dhillon, & Yang, 1997). RBD can represent a logic connection of components in a pre-treatment system. This method is use to illustrate whether the components is in series (dependence) parallel (independence) or redundant systems. The RBD model was constructed to represent a reliability model of the system by connecting different blocks/components in a system. In order to increase system reliability, the RBD structure could include series-parallel connection.

For the evaluation of reliability in systems, it is suggested to use RBD software. It is because RBD software is capable to model from simple series-parallel configurations to complex networks. The failure and repair data of each component for the figures in the RBD can be used to calculate many different reliability measures such as failure rate, MTTF, reliability, and availability (Sikos, 2010).

2.7.1 Series System

A system is said to be in series system if the failure of one or more components within a system must function for the system to succeed (Guangbin, 2007). Figure 2.2 shows an example for simple RBD in a system.

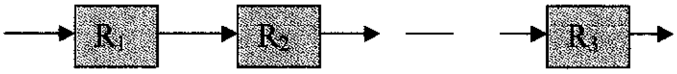


Figure 2.2: Series Connection

The system reliability for series connection is:

$$R = \prod_{i=1}^{n} Ri$$

$R_{system} = R_1 \times R_2 \times R_3$

The system reliability also can be written as:

$$R(t) = \exp(-t \sum_{i=1}^{n} \lambda i) = \exp\,(-\lambda t)$$

Where λ is the failure rate of the system and,

$$\lambda = \sum_{i=1}^{n} \lambda i$$

The mean time to failure of series system is:

$$MTTF = \int_{0}^{\infty} R\,(t) dt = \frac{1}{\sum_{i=1}^{n} \lambda i}$$

2.7.2 Parallel System

For a parallel connection, if one component fails the system can still functional because when the failure is detected; the standby component will switch on and performs the function (Guangbin, 2007). Figure 2.3 shows an example for simple RBD in a system.

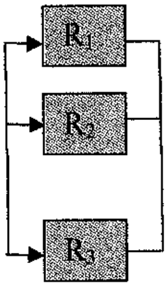


Figure 2.3: Parallel Connection

The system reliability for parallel connection is:

$$R = 1 - \prod_{i=1}^{n} (1 - Ri)$$

$R_{system} = 1 - (1 - R_1) \times (1 - R_2) \times (1 - R_3)$

If the component is modeled with the exponential distribution with failure rate λ, the system reliability can be written as:

$$R(t) = 1 - [1 - \exp(-\lambda t)]^n$$

Where λ is the failure rate of the system and,

$$\lambda = \sum_{i=1}^{n} \lambda i$$

The mean time to failure of parallel system is:

$$MTTF = \int_{0}^{\infty} R\ (t)dt = \frac{1}{\lambda}\sum_{i=1}^{n}\frac{1}{i}$$

2.5.3 Redundant System

A redundant system contains one or more standby components in system configuration. These standby units will enable the system to continue the function when the primary unit fails. Failure of the system occurs only when some or all of standby units fail. Implementing redundancy system in design can enhance system reliability (Guangbin, 2007). One of the commonly used forms of the redundancy is the standby redundancy. In a standby redundant system, some additional paths are created for the proper functioning of the system. Standby unit is support to increase the reliability of the system (ReliaSoft Corporation). In general there are 3-types of standby which are cold, hot and warm standby. Cold standby means that the redundant components cannot fail while they are waiting. Please refer to table 2.2 for example of cold standby systems.

Table 2.2: Example of Cold Standby Systems

Cold Standby Systems with a Perfect Switching System	
System Reliability	$R(t) = \ (1 + \lambda t)e^{-\lambda t}]$
MTTF	$\sum_{i=1}^{n}\frac{1}{\lambda} = \frac{n}{\lambda}$
Cold Standby Systems with an Imperfect Switching System	
System Reliability	$R(t) = \ e^{-\lambda t}[1 + \frac{\lambda}{\lambda o}(1 - e^{-\lambda o t}$
MTTF	$\int_{0}^{\infty} R(t)dt = \frac{1}{\lambda} + \frac{1}{\lambda o} - \frac{\lambda}{\lambda o(\lambda + \lambda o)}$

CHAPTER 3

METHODOLOGY

3.0 METHODOLOGY

3.1 Research Methodology

There are several methods for conducting performance evaluation of Pre-treatment unit (PTU) which are:

i. Preliminary research to understand the function, components and process flow of PTU.
ii. Construct functional block diagram of PTU.
iii. Data collection of failure rate, MTBF, MTTR for PTU system.
iv. Development of reliability data set. Need to analyze failure rate and previous maintenance data in order to improve system reliability.
v. Construction of RBD to check whether PTU system is in parallel or serial design.
vi. Verify RBD model with expert. The RBD that has been developed by researcher will be send to reliability engineer from PGB for verification and modification.
vii. Insert all useful data such as reliability data set and maintainability analysis into RBD.
viii. RBD simulation.
ix. Verify the result of simulation with expert.
x. Result analysis and discussion
xi. Report writing.

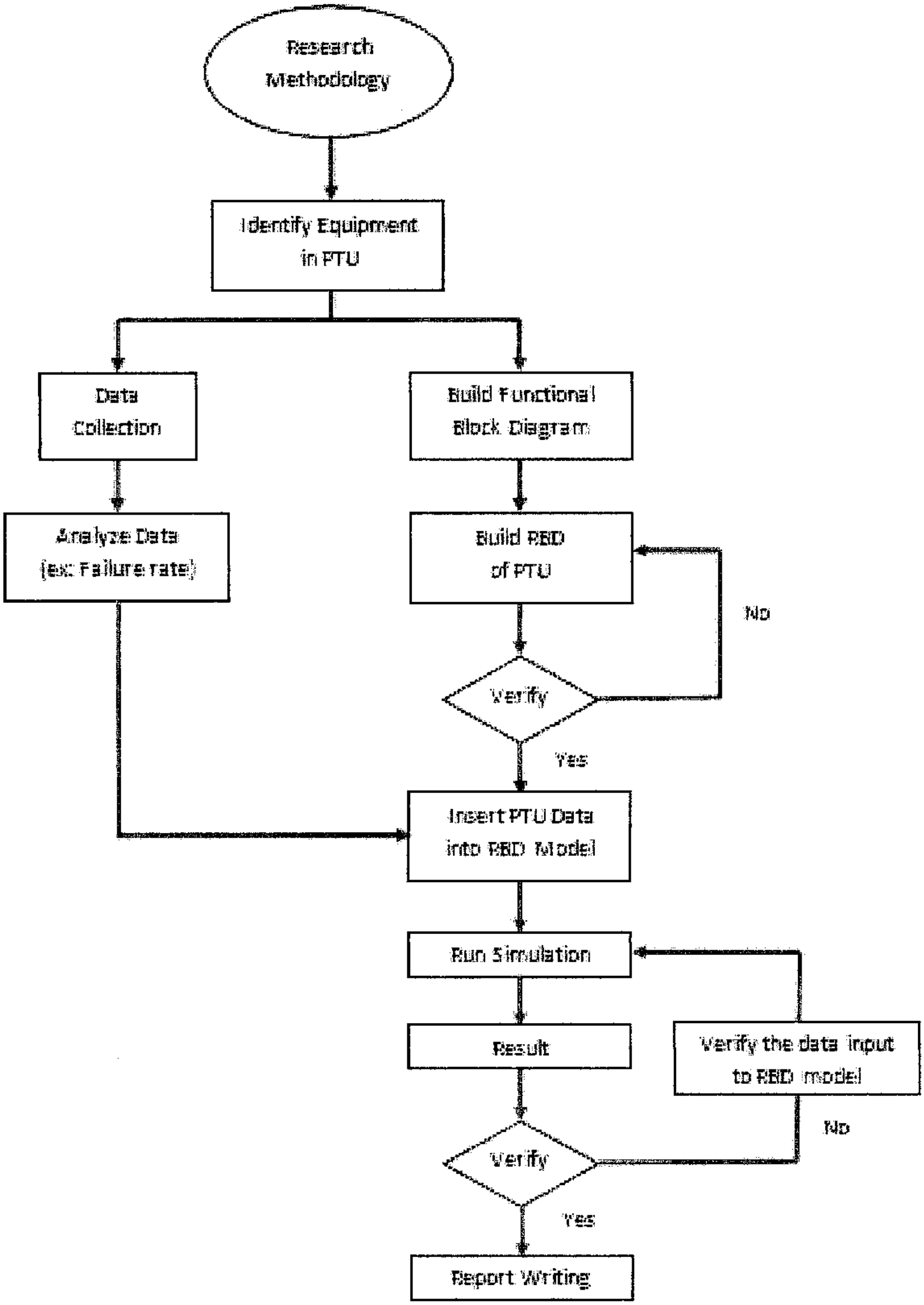


Figure 3.1: Research Methodology

3.2 Project Activity

This research mainly involve with study of Pre-treatment system and software practice. The study of PTU can be done by checking the plant and instrument diagram (P&ID) and check previous maintenance operation. The P&ID were analyzed to check the functions of each components and also to recognize the components that can cause system failure. For data analysis, there are several steps needed to analyze the data before data can be used. The step to determine time to failure model will be described later.

Since the construction of reliability block diagram (RBD) need to be done by using software which is BlockSim7, it is important to learn and practice the software. The software can be learning by referring to training guide of BlockSim7. Besides, this project also required in using Microsoft excels.

3.3 Time to Failure Model

Data analysis is needed to make predictions about the life of all components in the system by fitting as statistical distribution to life data from a representative sample of units. The parameterized distribution for the data set can then be used to estimate important life characteristics of the product such as reliability or probability of failure at a specific time, the mean life and the failure rate. In general, life data analysis required some steps which are:

- Life data collecting for the system.
- Select a lifetime distribution that will fit the data and model the life of the product.
- Estimate the parameters that will fit the distribution to the data.
- Generate plots and results that estimate the life characteristics of the product, such as the reliability or mean life.

There are different types of life data and because each type provides different information about the life of the product, the analysis method will vary depending on the data type. Please refer to figure 3.2 for detail step to determine time to failure model.

3.3.1 Data Homogeneity

Homogeneous data are drawn from a single population. This means that, all outside processes that could potentially affect the data must remain constant for the complete time period of the sample. It is important to determine if a set of data is homogeneous before any statistical technique is applied to it. It is because, homogenous data can be combined. Otherwise, non homogeneous data need to treat separately. Non homogeneous data are caused when artificial changes affect the statistical properties of the observations through time. These changes may be abrupt or gradual, depending on the nature of the disturbance. Logically, it is almost impossible to obtain perfectly homogeneous data. This is due to unavoidable changes in the area surrounding the observing station will often affecting the data.

3.3.2 Graphical Test

Graphical test is the simplest method in order to obtain results in accelerated life testing analyses and life data. The graphical method is used to estimate the parameters of accelerated life data by generating two types of plots. Here is the method for graphical test according to reference (ReliaSoft Corporation). First, the life data at each individual stress level are plotted on a probability paper appropriate to the assumed life distribution (*i.e.* Weibull, exponential, or lognormal). The parameters of the distribution at each stress level are then estimated from the plot. Once these parameters have been estimated at each stress level, the second plot is created on a paper. The parameters of the life-stress relationship are then estimated from the second plot. The life distribution and life-stress relationship are then combined to provide a single model that describes the accelerated life data.

3.3.3 Mann Test

Sometimes distributions of variables do not show a normal distribution, or the samples taken are so small that one cannot tell if they are part of a normal distribution or not. So, The Mann-Whitney U-test needs to be used in these situations. The Mann-Whitney U-test is used to test whether two independent samples of observations are drawn from the same or identical distributions (Mann Whithey U-Test). One of the advantages for this test is that the two samples under consideration may not necessarily have the same number of observations. Basically, the test involves two important assumptions. The first assumption is that the two samples are independent of each other and random. The second assumption state that the observations are numeric or ordinal and arranged in ranks.

3.3.4 Laplace Test

The purpose of Laplace test is to determine whether discrete event in a process have a trend. This test indicates whether a trend exist or does not exist for historical failure data. This means that Laplace test gives an indication whether the variation in the age at failures for a system is simply due to statistical (seasonal, cyclical, irregular) variation or due to an actual improving or deteriorating trend. There are many applications that using Laplace test in order to determine the trend for failure data. For example, Laplace test can be used to validate the use of constant failure rate model in determining the reliability of a repairable system. Besides, the Laplace test can be used to quantify the systems that need further analysis and possible preventive and corrective actions.

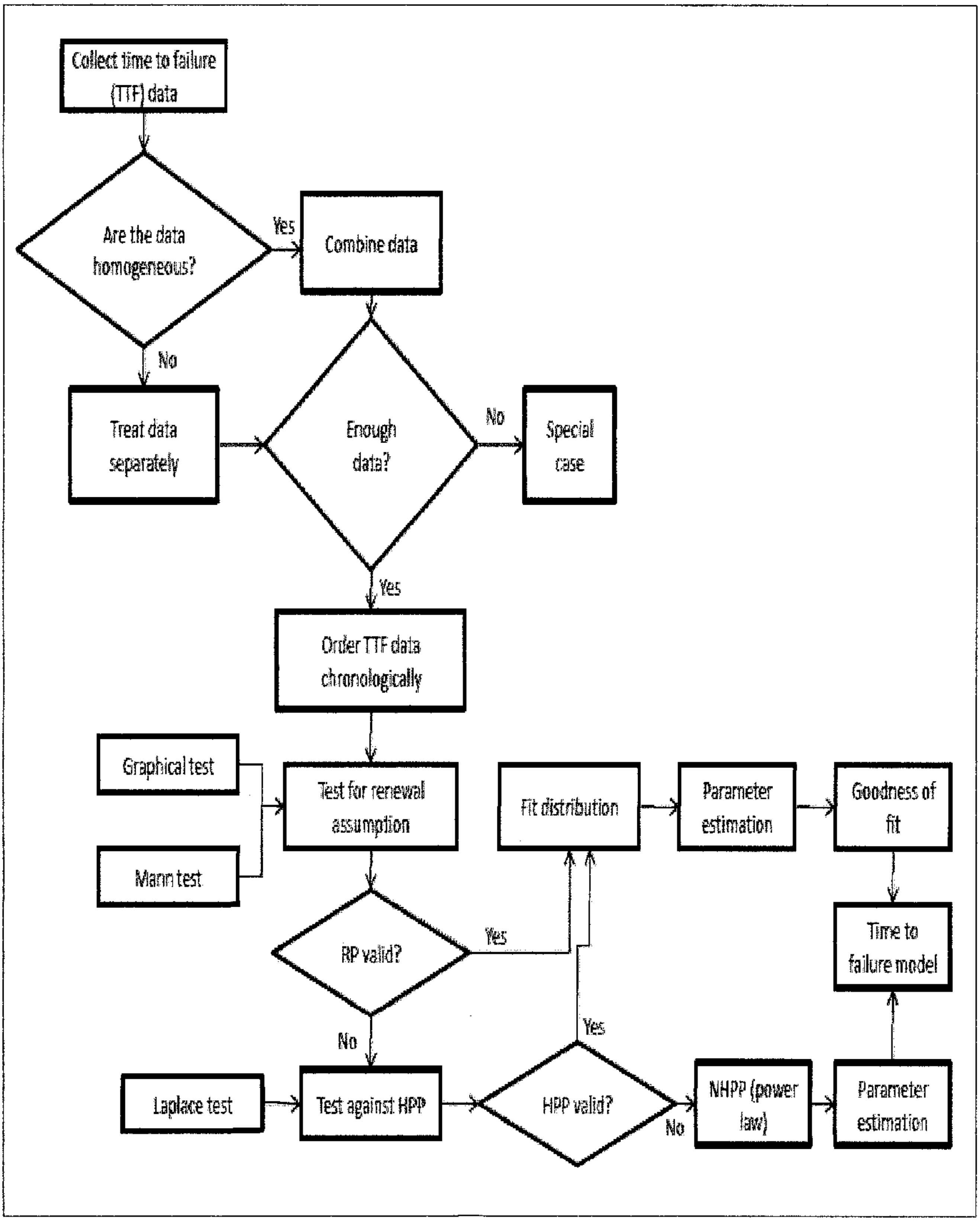


Figure 3.2: Step to Determine Time to Failure Model

3.4 System Familiarization of GPP PTU

The main purpose of PTU for GPP is:

- To separate entrained liquids from the gas feeds.
- To remove solid contaminants from gas and liquid feeds from the feed gas.
- To remove chlorides from the feed gas. Chloride removal is essential to prevent stress corrosion cracking in downstream units.
- To separate condensed water from liquid feeds.
- Dehydrates combined liquids in molecular sieve driers.

Based on the study of PTU (training module process), PTU is consist of some important equipments. The list and functions of each component is described at table 3.1.

Table 3.1: List of Components and Function of PTU

Components	Function
Inlet Separator	The upper drum is used to separate liquid from bulk flow of feed gas while the lower drum is designed for vapor separation from bulk liquid flow.
Feed Gas Filter	To remove solid materials and to separate small amounts of liquid in the feed gas.
Feed Liquid Filter	To remove solid materials and to separate small particles the feed liquid.
Decanter Drum	Consist of 3 phase separator for flashed hydrocarbon vapor, hydrocarbon liquid and water. Used to collect and remove any free water that might be mixed with the liquid hydrocarbon feed.
Coalescer Drum	To remove water from hydrocarbon fluid.

Condensate Dryers	To remove water down to 1.0 ppmw.
Chloride Scrubber	To remove chloride from feed gas train. Chloride removal is important to prevent chloride stress corrosion cracking in downstream unit.
Chloride Scrubber Make-up Pump	Provide continues measured flow of boiler feed water.
Chloride Scrubber Waste Water Pit	Emergency use
Chloride Scrubber Waste Water Pump	Emergency use
Feed Gas Heater	Used to raise gas from 30 ° C to 37 ° C to avoid hydrate problems downstream
Front End Turbo Compressor	To prevent feed gas from falling into its critical region in downstream LTSU.
AGR Inlet Separator	Separate condensed liquid from expanded feed gas.

3.5 Construction of Reliability Block Diagram

There are certain assumption has been made based on general engineering knowledge during construction of RBD. Firstly, only active components are considered to be main focus in this research. This is because the reliability is usually impaired by functional failure of active component not due passive component. The examples of active component are compressor, pump, and heat exchanger. The examples of passive component are pipe and tank.

The constructions of RBD start with study and analyze the components of PTU by referring to P&ID of PTU. This step will give some of information about component and function of PTU. Then, it is required to analyze the process flow diagram (PFD) in order to know the flow and equipment involved in the process of PTU. Generally, a PFD shows only the major equipment and doesn't show all of the equipment like P&ID. In addition, PFD will show the connection of the components in the system and also tell which equipment can affect operation of the system. The PFD for PTU is shown in the figure 3.3. Lastly, the construction of RBD can start after identified the main components of PTU including their connection. Figure 3.4 shows the RBD of PTU that has been developed by researcher. The RBD will be verified by reliability engineer from PGB. The result for the finalized RBD by reliability engineer will be discussed later in result section.

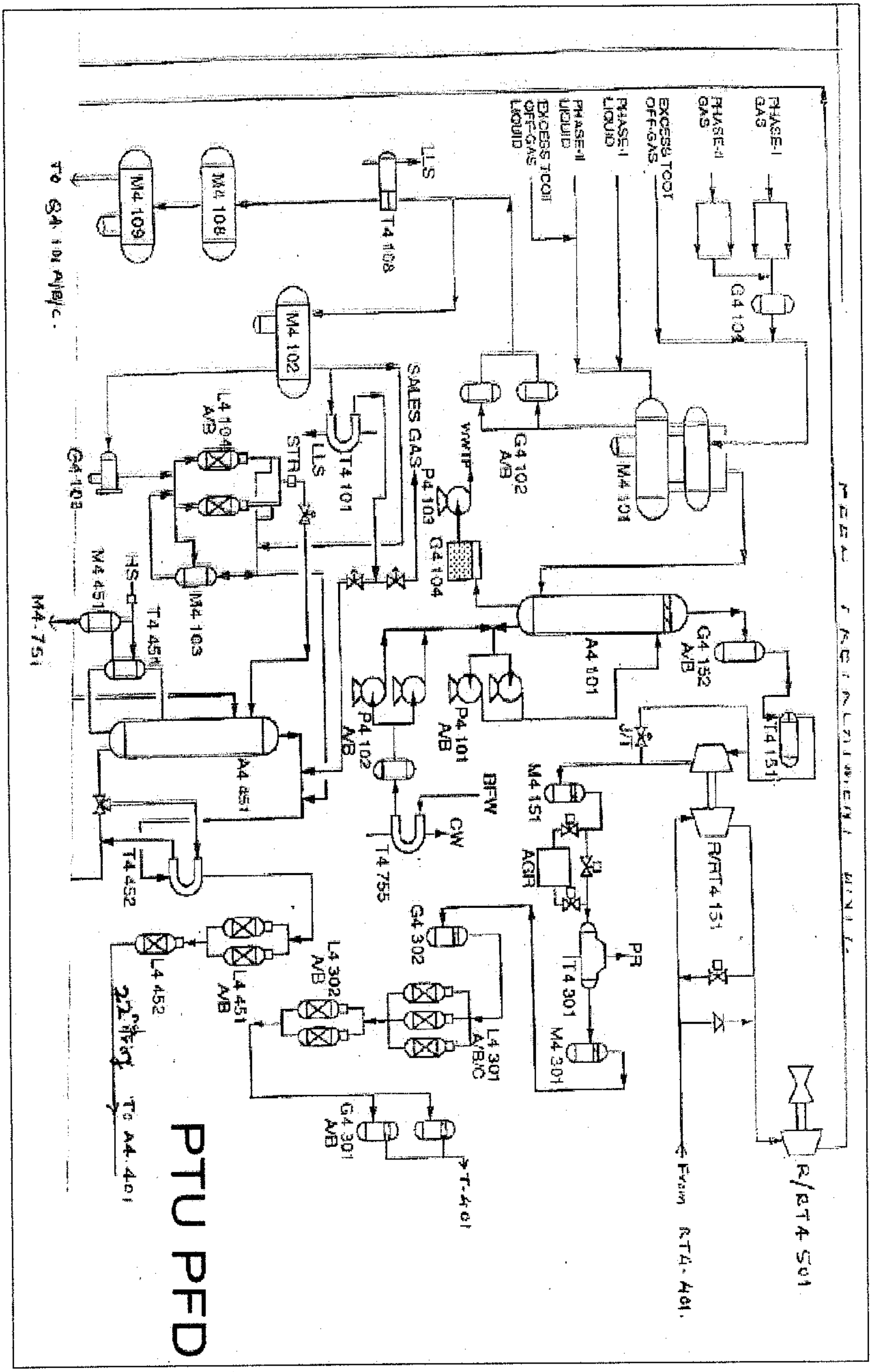


Figure 3.3: Process Flow Diagram for PTU

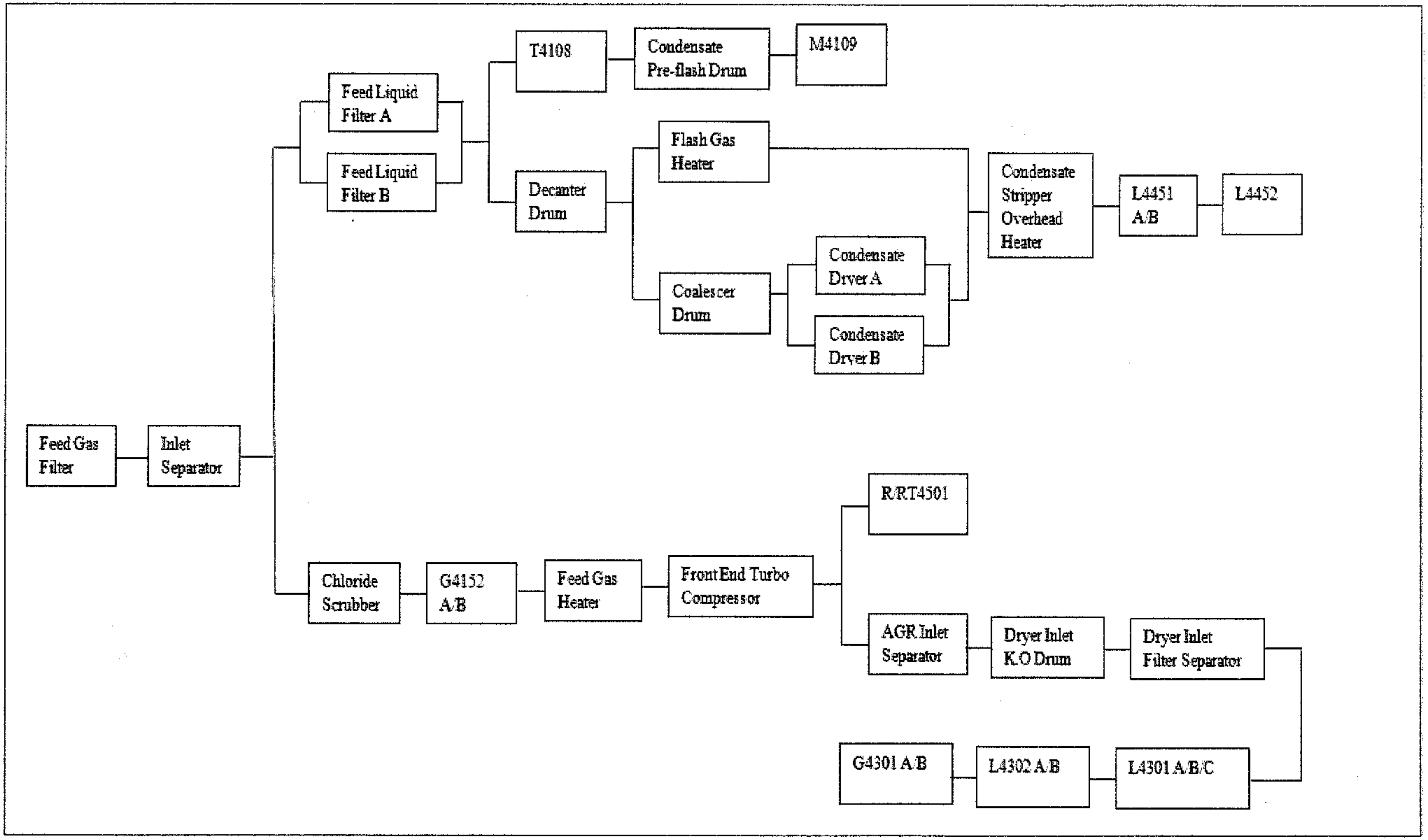


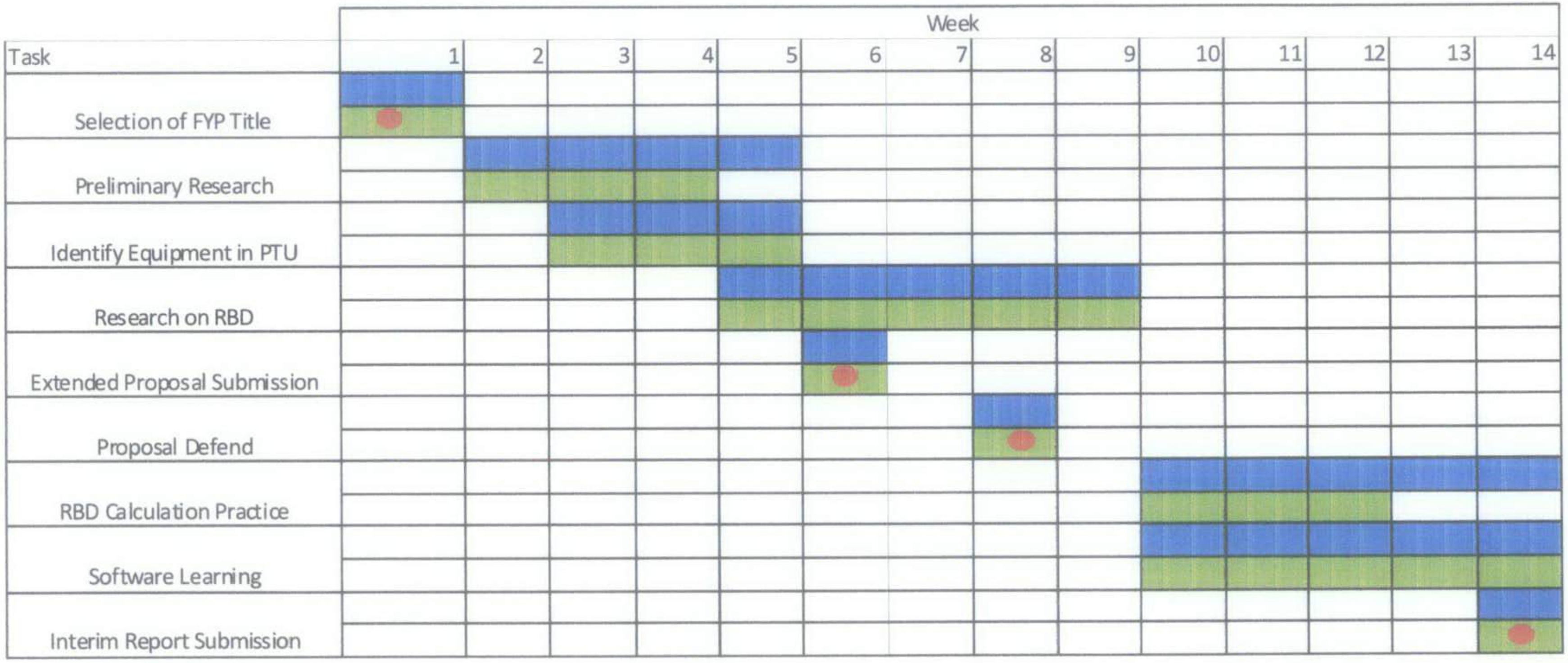
Figure 3.4: The First Draft of RBD for PTU

Table 3.2: Equipment Code of PTU

Equipment Code	Name
M4 101	Inlet Separator
M4 102	Decanter Drum
M4 103	Condensate Transfer Drum
M4 108	Condensate Pre-flash Drum
M4 151	AGR Inlet Separator
M4 301	Dryer Inlet K.O Drum
M4 201	Feed Gas Separator
A4 101	Chloride Scrubber
A4 451	Condensate Stripper
T4 101	Flash Gas Heater
T4 452	Condensate Stripped Overhead Heater
T4 151	Feed Gas Heater
P4 103	Chloride Scrubber Waste Water Pump
P4 101	Circulating Pump
P4 102	Chloride Scrubber Make Up Pump
G4 101	Feed Gas Filter
G4 102	Feed Liquid Filter
G4 104	Chloride Scrubber Waste Water Pit
G4 741	Arsenic Removal Unit
G4 103	Coalescer Drum
G4 302	Dryer Inlet Filter Separator
L4 104	Condensate Dryers
R/RT4 151	Front End Turbo Compressor

3.6 Gantt Chart

Table 3.3: Project timeline and execution plan for FYP 1



	Week													
Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of FYP Title	🟦													
	🟩 ●													
Preliminary Research		🟦	🟦	🟦	🟦									
		🟩	🟩	🟩										
Identify Equipment in PTU			🟦	🟦	🟦									
			🟩	🟩	🟩									
Research on RBD					🟦	🟦	🟦	🟦	🟦					
					🟩	🟩	🟩	🟩	🟩					
Extended Proposal Submission						🟦								
						🟩 ●								
Proposal Defend								🟦						
								🟩 ●						
RBD Calculation Practice										🟦	🟦	🟦	🟦	🟦
										🟩	🟩	🟩		
Software Learning										🟦	🟦	🟦	🟦	🟦
										🟩	🟩	🟩	🟩	🟩
Interim Report Submission														🟦
														🟩 ●

Suggested Milestone ●

🟦	Planned Task
🟩	Completed Task

Table 3.4: Project timeline and execution plan for FYP 2

Task	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Data Collection	🟦	🟦												
Build Functional Block Diagram			🟦											
Analyze Data			🟦 ●	🟦										
Build RBD of PTU					🟦 ●	🟦								
Verify RBD							🟦							
Insert PTU data into RBD								🟦						
Run Simulation									🟦					
Verify Result Simulation										🟦				
Report Writing														
Progress Report Submission								🟦						
Pre-EDX											🟦			
Dissertation Writing									🟦	🟦 ●	🟦			
Draft Report Submission											●	🟦		
Dissertation Submission (soft)													🟦	
Technical Paper submission													🟦	
Oral Presentation													●	🟦
Dissertation Submission (hard)													●	🟦

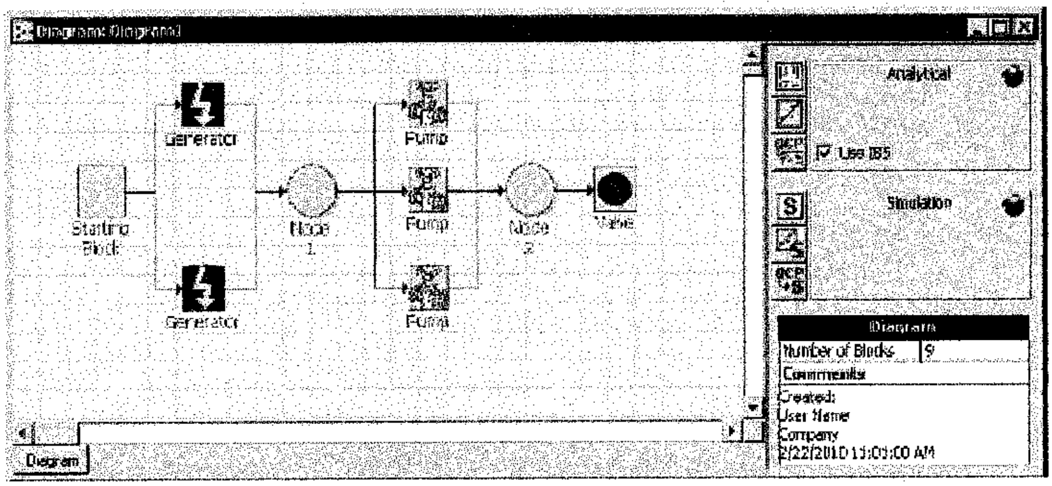
SUGGESTED MILESTONE ●

🟦	Planned Task
🟩	Completed Task

3.7 Software

3.7.1 BlockSim Software

Based on previous journal paper (Sikos, 2010), the construction of reliability block diagram is needed in finding the system reliability of the equipment. RBD is a drawing and calculation tool used to model complex system. After the blocks diagram have been constructed and inserted with appropriate data, the reliability, availability, failure rate and MTBF of the equipment can be calculated. Please refer to figure 3.2 for example of RBD by using Blocksim 7. The figure 3.5 was taken from (Training guide BlockSim version 7, ReliaSoft Corporation)



☑ Use IBS

Number of Blocks 9

Comments

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Figure 3.5: Example of RBD by using BlockSim 7

3.7.2 Microsoft Excel

Microsoft Excel is used to assist some of the calculation in this research. This software is useful in sorting the data.

CHAPTER 4

RESULT AND DISCUSSION

4.0 RESULT AND DISCUSSION

Throughout the end of this Final Year Project, expected outcomes of the study would be:

- The components of pre-treatment unit can be identified and the critical components for PTU are known.
- The construction of reliability block diagram (RBD) can be completed.
- All data generated from RBD software can be recorded.

4.1 Reliability Block Diagram of PTU

After completion of RBD for PTU that has been developed, the researcher needs to submit the proposed RBD to expert for verification purposed. The RBD that has been developed by researcher has many weaknesses due to several reasons. Firstly, the previous RBD has been developed by referring to PFD and PTU Training Module Process. PTU Training Module Process did not describe and gives detail about all component o PTU. So, there are certain components that cannot be identified by researcher. Secondly, it is hard to identify the main component of PTU since the data and reference for PTU is limited. In order to establish a reliability model for the PTU, it is necessary to divide the plant into meaningful systems. The finalized RBD has been divided into four systems.

4.1.1 General Assumptions

1. Failure: Total system shutdown or trip.
2. Process slowdowns are not considered as failure.
3. PTU system reliability is only dependent upon PTU gas line with one train.
4. Piping reliability is assumed as 100% (failures due to leaks are not included).
5. PTU reliability is measured based on product (C2 or C3 production).
6. Gases/liquid TCOT is not included in the model.
7. Regeneration and Blowdown system are considered another subsystem supporting the whole plant.
8. The failure of one of the following equipment will cause process slowdown but not effecting reliability: L301 (DHU Dehydrate), L302 (DHU Dehydrate), G102 (PTU Liquid).
9. XV 1605 and XV 1606 are part of AGRU subsystem under C2 Production.
10. The model is applicable to current operation mode including bypasses (ie RT 151, G 104).

4.1.2 Reliability Block Diagram System 1 (PTU Gas C2)

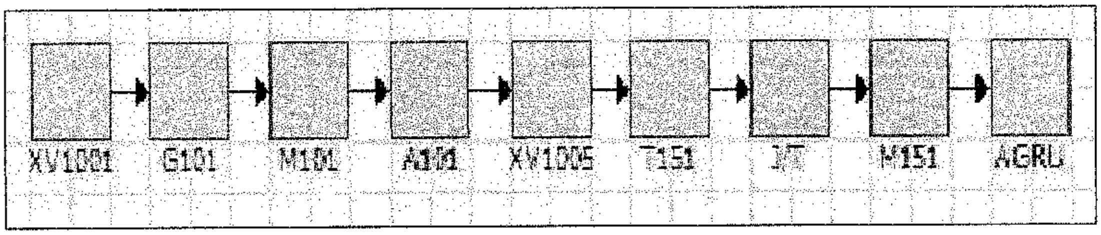


Figure 4.1: RBD for PTU Gas C2 (BlockSim Software)

4.1.3 Reliability Block Diagram System 2 (PTU Gas C3)

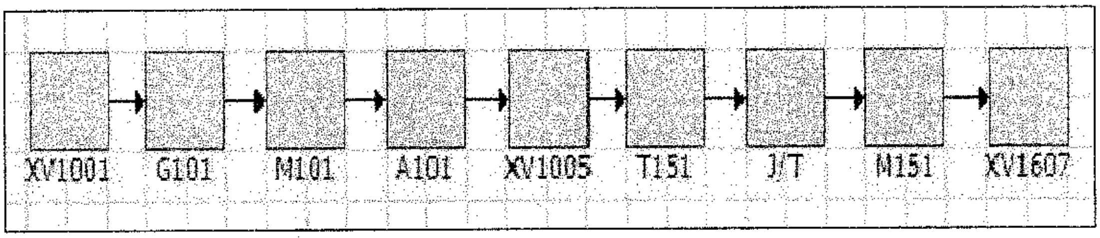


Figure 4.2: RBD for PTU Gas C3 (BlockSim Software)

4.1.4 Reliability Block Diagram System 3 (PTU Liquid with Blowdown)

If blowdown is not required, then the reliability of Blowdown system is assumed as 100%.

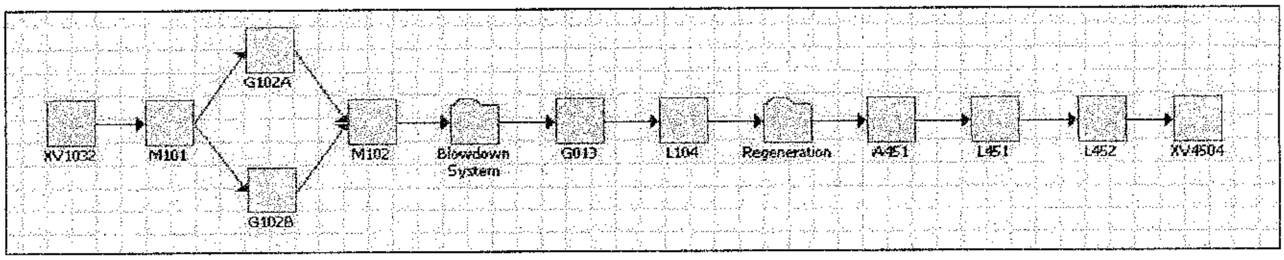


Figure 4.3: RBD for PTU Liquid with Blowdown (BlockSim Software)

4.1.5 Reliability Block Diagram System 4 (PTU Liquid without Blowdown)

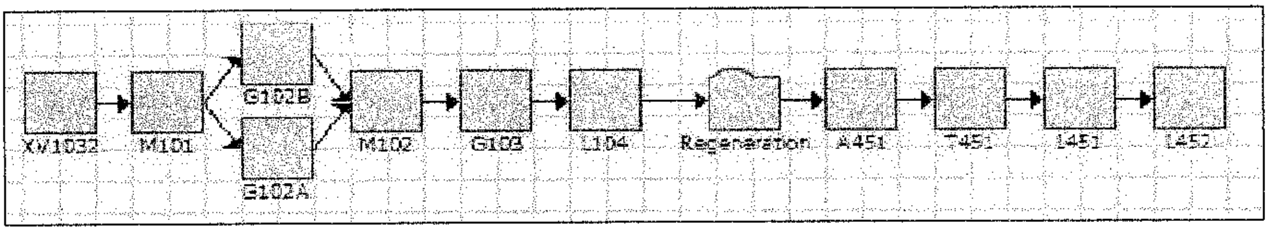


Figure 4.4: RBD for PTU Liquid without Blowdown (BlockSim Software)

4.1.6 PTU Regeneration

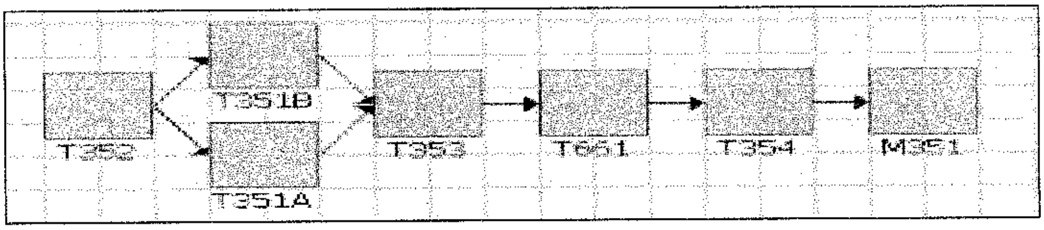


Figure 4.5: RBD for PTU Regeneration

4.2 Data Collection

This task required the researcher to collect and gather failure rate of each equipment for PTU. The data sources are Offshore Reliability Data Handbook, 1st Edition (1984) and Offshore Reliability Data Handbook, 5th (2009).

Basically, not all particular data are available within these sources. So, the researcher need to use his own judgment based on his knowledge and also by referring to the opinion from expert and his supervisor. For example, the failure rate for some equipment is determined based on other equipment from OREDA that has similar function. Refer to table 4.1 for MTTF of all equipments by using mean failure rate in OREDA.

Table 4.1: MTTF of Equipment using Mean Failure Rate (Data from OREDA)

Code	Equipment	Failure Rate (10^6 hours)	Mean MTTF (hr)	Remarks	Data Source
A101	Chloride Scrubber	23.47	42.608E+3	Critical	OREDA
A451	Condensate Stripper	10.01	99.9001E+3	Non Critical	OREDA
G101	Feed Gas Filter	12	83.3333E+3	Critical	OREDA
G102	Feed Liquid Filter	12	83.3333E+3	Critical	OREDA
G103	Coalescer Drum	32.29	30.9693E+3	Critical	OREDA
L451	Contaminant Removal	67.16	14.89E+3	Incipient/ Non Critical	OREDA
L452	Mercury Removal	67.16	14.89E+3	Incipient/ Non Critical	OREDA
M101	Inlet Separator	32.39	30.8737E+3	Critical	OREDA
M102	Decanter Drum	12.89	77.5795E+3	Critical	OREDA

M151	AGR Inlet Separator	32.39	30.8737E+3	Critical	OREDA
M351	Knock Out Drum	1.2	833.333E+3	Critical	OREDA
T151	Feed Gas Heater	41.64	24.0154E+3	Critical	OREDA
T351	Heat Exchanger	11.925	83.85744E+3	Incipient/ Non Critical	OREDA
T352	Heat Exchanger	11.925	83.85744E+3	Incipient/ Non Critical	OREDA
T353	Heat Exchanger	11.925	83.85744E+3	Incipient/ Non Critical	OREDA
T354	Heat Exchanger	11.925	83.85744E+3	Incipient/ Non Critical	OREDA
T451	Heat Exchanger	11.925	83.85744E+3	Incipient/ Non Critical	OREDA
T661	Heat Exchanger	11.925	83.85744E+3	Incipient/ Non Critical	OREDA
XV1001	Shut Off Valve	3.6	277.7778E+3	Critical	OREDA

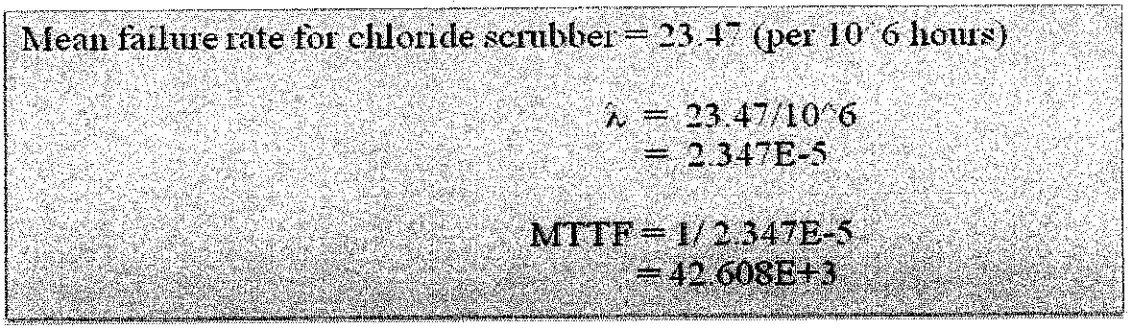
XV1005	Shut Off Valve	3.6	277.7778E+3	Critical	OREDA
XV1032	Shut Off Valve	3.6	277.7778E+3	Critical	OREDA
XV1607	Shut Off Valve	3.6	277.7778E+3	Critical	OREDA
XV4504	Shut Off Valve	3.6	277.7778E+3	Critical	OREDA
AGRU	Acid Gas Removal Unit	NO	NO	Assume as static equipment	
J/T	Joule Thomson Valve (By-pass Valve)	NO	NO	Assume as static equipment . Use if turbo-expander is out of service.	
	Blowdown System	NO	NO	Assume as static equipment	
L104	Condensate Dryer	NO	NO	Assume as static equipment	

The failure rate data from OREDA follows exponential distribution. The exponential distribution is a very frequently used distribution in reliability engineering. Due to its simplicity, it has been widely employed even in cases to which it does not apply. The exponential distribution is used to describe units that have a constant failure rate (Exponential Distribution). MTTF is calculated by using this formula:

λ = constant failure rate, in failures per unit of measurement. In this research λ is used as failures per hour.

MTTF = $1/\lambda$

Please refer to figure 4.6 for calculation example.



Mean failure rate for chloride scrubber = 23.47 (per 10^6 hours)

λ = 23.47/10^6
= 2.347E-5

MTTF = 1/ 2.347E-5
= 42.608E+3

Figure 4.6: MTTF Calculation example

4.3 Static Reliability

Static reliability basically did not dependent on time. If the system is considered to have a static reliability, the system reliability did not affect by time. By assuming that all equipment's have static reliability, the researcher can check the reliability of PTU. Besides, what-if analysis can be done by referring to system reliability of PTU in order to improve overall system reliability.

4.3.1 Static Reliability of PTU

For static reliability, researcher wants to see the reliability of each system if all equipments in system are assumed to have same reliability value. For example, if all equipments inside PTU Gas C2 system are assumed to have reliability of 0.9, the reliability for this system is 0.3874. Refer to table 4.2 for static reliability of PTU.

Table 4.2: Static Reliability for PTU

System	Reliability of Each Component	Probability of Failure	System Reliability
PTU Gas C2	0.9	0.1	0.3874
	0.92	0.08	0.4722
	0.94	0.06	0.573
	0.96	0.04	0.6925
	0.98	0.02	0.8337
PTU Gas C3	0.9	0.1	0.3874
	0.92	0.08	0.4722
	0.94	0.06	0.573
	0.96	0.04	0.6925
	0.98	0.02	0.8337
PTU Liquid with Blowdown	0.9	0.1	0.2242
	0.92	0.08	0.3072
	0.94	0.06	0.4175
	0.96	0.04	0.5629
	0.98	0.02	0.7531
PTU Liquid without Blowdown	0.9	0.1	0.2242
	0.92	0.08	0.3072
	0.94	0.06	0.4175
	0.96	0.04	0.5629
	0.98	0.02	0.7531

4.3.2 What-if Analysis for Static Reliability of PTU

Based on the result for static reliability of each system, the resulting reliability for PTU Liquid with Blowdown system is the lowest. So, the researcher chooses to analyze for this mode. The task is to check which equipment can give high impact on system reliability if the reliability of that equipment is improved.

Table 4.3: Analysis of Static Reliability for PTU Liquid with Blowdown

Equipment	Base Reliability	Improved Reliability	System Reliability	Resulting System Reliability After Improvement
XV1032	0.9	0.94	0.2242	0.2342
M101	0.9	0.94	0.2242	0.2342
G102A	0.9	0.94	0.2242	0.2251
G102B	0.9	0.94	0.2242	0.2251
M102	0.9	0.94	0.2242	0.2342
Blowdown System (Static Equipment)				
M108 (sub)	1	NO	0.2242	NO
M108 (sub)	1	NO	0.2242	NO
G103	0.9	0.94	0.2242	0.2342
L104	0.9	0.94	0.2242	0.2342
Regeneration (Main component)				
T352 (sub)	0.9	0.94	0.2242	0.2342
T351A (sub)	0.9	0.94	0.2242	0.2251
T351B (sub)	0.9	0.94	0.2242	0.2251
T353 (sub)	0.9	0.94	0.2242	0.2342
T661 (sub)	0.9	0.94	0.2242	0.2342
T354 (sub)	0.9	0.94	0.2242	0.2342
M351(sub)	0.9	0.94	0.2242	0.2342
A451	0.9	0.94	0.2242	0.2342
L451	0.9	0.94	0.2242	0.2342
L452	0.9	0.94	0.2242	0.2342
XV4504	0.9	0.94	0.2242	0.2342

By referring to the table 4.3, basically by improving the reliability of any component in series will result in higher impact than improving reliability of component in parallel. The analysis by assuming all equipment's have a static reliability cannot give clear result on which equipment should be prioritized in order to improve system reliability. Besides, it's hard to detect which equipment is in critical condition. So, the researcher conducts further reliability analysis by referring to OREDA data. The data collected from this handbook basically follow exponential distribution. Equipment that has failure which follows exponential distribution will have constant failure rate.

4.4 Reliability of PTU (OREDA)

The data sample is collected from OREDA 1984 and 2009. Basically, the OREDA database shows the failure data based on 4 categories. The 4 categories included critical, degradation, incipient and unknown severity. A critical failure can be described as a failure that can causes immediate and complete loss of a system's capability of providing its output (Langseth & Henry, 2004). A degraded failure is defined as a failure that prevents the system from providing its output within specifications and may develop into critical failure in time (Langseth & Henry, 2004). An incipient failure is a failure that not immediately causes loss of the system's capability of providing its output, but can develop to a critical or degraded failure in the near future if not attended to. For simplicity, the data in OREDA is distinguished between critical and no-critical value. Based on previous research paper, incipient and degraded failures not be differentiated and can be classified as "degraded" (Langseth, 2004). For this research the, incipient and degraded is classified as non-critical. The value of MTTF from table then is inserted into Blocksim software to calculate system reliability of PTU for all modes. Refer to table 4.4 for reliability result using mean failure rate from OREDA.

Table 4.4: Reliability for Each System using Mean Failure Rate for 720 hours (Data from OREDA)

System	Equipment	Reliability	Rank (*)	System Reliability
PTU Gas C2	XV1001	0.9974	6	0.8985
	J/T	1	8	
	AGRU	1	9	
	XV1005	0.9974	7	
	G101	0.9914	5	
	M101	0.9769	2	
	A101	0.9836	4	
	T151	0.9705	1	
	M151	0.9769	3	
PTU Gas C3	XV1001	0.9974	6	0.8962
	XV1005	0.9974	7	
	XV1607	0.9974	8	
	J/T	1	9	
	G101	0.9914	5	
	M101	0.9769	2	
	A101	0.9836	4	
	T151	0.9705	1	
	M151	0.9769	3	
PTU Liquid with Blowdown	XV1032	0.9974	10	0.8185
	G102A	0.9914	7	
	G102B	0.9914	8	
	M101	0.9769	4	
	M102	0.9908	6	
	Blowdown	1	12	
	G103	0.977	5	
	L104	1	13	
	Regeneration	0.9653	3	
	A451	0.9928	9	
	L451	0.9528	1	
	L452	0.9528	2	
	XV4504	0.9974	11	
PTU Liquid without	XV1032	0.9974	11	0.8136
	M101	0.9769	4	
	G102B	0.9914	7	

Blowdown	G102A	0.9914	8	
	M102	0.9908	6	
	G103	0.977	5	
	L104	1	12	
	Regeneration	0.9653	3	
	A451	0.9928	10	
	T451	0.9915	9	
	L451	0.9528	1	
	L452	0.9528	2	

Remark (*): Rank is to identify the critical equipment with lowest reliability for each mode. Smaller number means the equipment has the lowest reliability and should be rank first for further improvement.

The reliability has been calculated for 1 month which is after 720 hours based on previous research (Yim et al, 1998). Please refer to table for reliability for each system by using mean failure rate from OREDA. PTU Gas C2 has highest reliability with 0.8985, followed by PTU Gas C with 0.8962, then PTU Liquid with Blowdown with 0.8185 and lastly PTU Liquid without Blowdown with 0.8136. PTU Liquid without blowdown has been chosen for sensitivity analysis. This is because this system has lowest reliability with 0.8136.

4.5 Sensitivity/what-if Analysis

Sensitivity analysis has been conducted for PTU Liquid without Blowdown. The purpose of sensitivity analysis is to find the method to improve the reliability for this system. The target is to improve the reliability of this system from 0.8136 to 0.87. The methods that can improve overall reliability are by improving individual component and providing redundancy (Heizer & Render, 2011). Based on reliability calculation, ranking has been made to determine the critical component that need to be attended first. The rank with lowest value shows that equipment has smallest reliability. So, the sensitivity analysis will follow this ranking. Refer to figure 4.5 for equipment reliability ranking.

Table 4.5: Equipment Reliability ranking for PTU Liquid without Blowdown

Equipment	Reliability	Rank
L451	0.9528	1
L452	0.9528	2
Regeneration	0.9653	3
M101	0.9769	4
G103	0.977	5
M102	0.9908	6
G102B	0.9914	7
G102A	0.9914	8
T451	0.9915	9
A451	0.9928	10
XV1032	0.9974	11
L104	1	12

Based on table 4.5, equipment L451 has lowest reliability with 0.9528. So, L451 has been ranked first for improvement at this system. The reliability improvement will continue with other equipment at this system based on the ranking until target reliability of 0.87 has been achieved. There are two methods to improve system reliability. Firstly, improve individual component. Secondly, provide redundancy. Based on these methods, the researcher has conducted three reliability improvement options. The options include:

1. Improve reliability of each component.
2. Provide redundancy.
3. Combination of reliability improvement for each equipment and redundancy.

4.5.1 Improve Reliability of Each Component

One of the ways to improve reliability of equipment is by increasing MTTF. For sensitivity analysis at PTU Liquid without Blowdown system, the researcher assumes to increase the MTTF of component 100% from original MTTF. The analysis will be conducted at equipment having a low reliability based on ranking at table 4.5. Analysis will stop after target reliability of this system achieves 0.87. The original system reliability of this system is 0.8136. Refer to table 4.6 for the step to achieve target reliability by improving reliability of individual equipment.

Table 4.6: Improve individual equipment to achieve target reliability 0.87.

Step	Equipment	Base MTTF (hr)	Base equipment reliability	Improve 100% MTTF (hr)	Improve equipment reliability	System Reliability
Step 1	L451	14900	0.9528	29800	0.9761	0.8335
Step 2	L452	14900	0.9528	29800	0.9761	0.8539
Step 3	M101	30900	0.9769	61800	0.9884	0.8639
Step 4	G103	31000	0.977	62000	0.9884	0.874

In order to achieve the target reliability of 0.87, the researcher needs to improve reliability of four equipments. The equipments include L451, L452, M101 and G103. The analysis stopped after improving reliability of G103 since system reliability is 0.874 which is bigger than 0.87.

4.5.2 Improve System Reliability by Providing Redundancy

Redundant equipment has been added to equipment that has lowest reliability based on table 4.5. The target is to improve system reliability from 0.8136 to 0.87 by providing redundancy. Refer to table 4.7 for system reliability improvement after adding redundant equipment.

Table 4.7: Redundancy to Improve System Reliability

Step	Task	Description	System Reliability
Step 1	Add redundant equipment at L451	Redundant equipment is assumed to have similar reliability of L451 which is 0.9528.	0.852
Step 2	Add redundant equipment at L452	Redundant equipment is assumed to have similar reliability of L452 which is 0.9528.	0.8922

The sensitivity analysis is stopped after redundant equipment has been added to L452 since target system reliability has been achieved. The reliability of PTU Liquid without Blowdown has been increased from 0.8136 to 0.8922.

4.5.3 System reliability Improvement by Increasing Individual Equipment and Adding Redundant Component

For this task, the researcher has improved system reliability of PTU Liquid without Blowdown. The method to improve system reliability is:

- Improve reliability of equipment, and
- Add redundant equipment.

First, the reliability of equipment has been increased by improving 100% of original MTTF. Then the redundant equipment is added to equipment. These steps are repeated until target reliability for system is achieved. Refer to table 4.8 for the system reliability result after improvement. The analysis is stopped at step 2 after the system reliability has been improved from 0.8136 to 0.8922.

Table 4.8: Improve Reliability of Equipment and Provide Redundancy

Step	Equipment	Task	System Reliability
Step 1	L451	1. Increase MTTF of L451 from 14900 to 29800 hours. Reliability equipment improves to 0.9761. 2. Add redundant equipment to L451. Redundant equipment is assumed to have same reliability with improved L451 which is 0.9761.	0.8534
Step 2	L452	1. Increase MTTF of L451 from 14900 to 29800 hours. Reliability equipment improves to 0.9761. 2. Add redundant equipment to L451. Redundant equipment is assumed to have same reliability with improved L451 which is 0.9761.	0.8952

4.6 Cost Analysis to Select the Best Method for Improvement

Basically, the cost for equipment redundancy is more expensive than improving reliability of equipment. This analysis required the researcher to compare the cost of reliability improvement for each method and suggest the best method to improve reliability of PTU Liquid without Blowdown system. There are few assumptions has been made since researcher cannot find the actual cost for implementation of equipment reliability improvement and adding redundancy.

1. The total cost for adding redundancy equipment including installation is RM RM30, 000.
2. The total cost for improving reliability of equipment is RM10, 000.

4.6.1 Total Cost to Improve Reliability of Each Component

The total number of equipments need to be improved is 4.

The total cost = 4 Equipments X RM 10, 000

= RM 40, 000

4.6.2 Total Cost to Improve Reliability by Providing Redundancy

The total number of equipments added redundant equipment is 2.

The total cost = 2 Equipments X RM 30, 000

= RM 60, 000

4.6.3 Total Cost to Improve Reliability by Improve Reliability of Component and Providing Redundancy

The total number of equipments need to be improved is 2.

Cost = 2 Equipments X RM 10, 000

= RM 20, 000

The total number of equipments added redundant equipment is 2.

The total cost = 2 Equipments X RM 30, 000

= RM 60, 000

Total cost = RM 20, 000 + RM 60, 000

= RM 80, 000

4.6.4 Method Chosen for System Reliability Improvement

Based on the calculation for total cost, the best method to improve the reliability of PTU Liquid without Blowdown is by improving reliability of each component. The calculations show that this method has cheapest cost to increase the reliability of the system until achieved the target. The cost to improve the reliability of system to achieve the target by using this method is RM 40, 000.

The researcher not chooses this method based on cost only. Basically, adding redundant equipment will increase support requirement and costs. Adding more equipment will increase complexity to system. Increase in complexity due to addition of equipment will increase total failure to the system. As a result unscheduled maintenance will increase. Although adding redundancy will increase system reliability, but as a consequence the total failure rate of component will increase. Lastly, adding redundant equipment will consumes space. So, the researcher suggests improving system reliability of PTU Liquid without Blowdown by improving individual equipment.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The reliability analysis by using RBD model can evaluate whether the equipment has achieved the target reliability that has been setup by plant management or not. If the equipment has achieved the reliability target, the management should provide any task that can sustain current equipment performance. Besides, if the equipment did not achieve the reliability target, the management should identify what is the main problem that reduces the reliability of that equipment.

The target reliability for PTU Liquid without Blowdown has been selected for sensitivity analysis because this system has the lowest reliability with 0.8136. The purpose of the analysis is to improve the reliability at this system until achieve the target reliability of the system which is 0.87. The analysis covers all methods to improve system reliability. The methods include improve reliability of each equipment, provide redundancy and also combination of improve reliability of each equipment and redundancy. The researcher suggests improving reliability of system by improving reliability of individual equipment. The reason is this method requires cheapest investment which is RM 40, 000.

For static analysis of PTU RBD, basically by improving the reliability of any component in series will result in higher impact than improving reliability of component in parallel.

5.2 Recommendation

Basically the main purpose of this research is to evaluate the reliability of PTU for GPP at PGB. The researcher has completely identified the main equipment of PTU and constructs RBD for this system. PTU can be cut down into four systems. The systems include PTU Gas C2, PTU Gas C3, PTU liquid with blowdown and PTU liquid without blowdown. The analysis of system reliability of PTU by using actual data from PGB cannot be completed since they cannot provide the failure rate data on time. This data is importance in order to evaluate the reliability of each sub-system for PTU.

After consulting with respective supervisor and expert, the researcher continue the research and conduct analysis by using failure rate based on OREDA. The analysis by referring to OREDA data has certain weaknesses. Firstly, the data from OREDA has different geographic area and operating condition from the actual failure rate data from PGB. The operating condition can affect the failure time for equipment. Besides, the corrosive environment due to geographic area can reduce the reliability of equipment. In addition, there is no failure rate data for certain equipment in OREDA. So, the researcher need to use engineering judgments based on his knowledge and discussions with other experts when using the data from OREDA. For example, all heat exchangers are assumed to be the same and have similar failure rate. Besides, the failure rate for some equipment is determined based on other equipment that has similar function.

As for recommendation, the researcher suggests that the analysis of PTU should be done by using actual data from PGB. The actual failure rate data can evaluate whether PTU has achieved the target reliability of PGB or not. Besides, each plant should document every failure that occurred to equipment so that the data can be used for reliability analysis to improve performance of equipment. This research can be used as a guideline to evaluate the reliability performance of PTU or any system in GPP when the actual failure rate data is present.

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