BACHELOR THESIS – ME 184834

SOCIETAL RISK ASSESSMENT ON 60 MW BARGE MOUNTED POWER PLANT IN SOUTH EAST SULAWESI

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INSTITUT TEKNOLOGI SEPULUH NOPEMBER
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2019

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APPROVAL FORM I

SOCIETAL RISK ASSESSMENT ON 60 MW BARGE MOUNTED POWER PLANT 60 MW IN SOUTH EAST SULAWESI

BACHELOR THESIS

Submitted to Comply One of The Requirement
to Obtain a Bachelor Engineering Degree
On
Reliability, Availability, Management and Safety (RAMS)
Bachelor Degree of Marine Engineering
Fakultas Teknologi Kelautan
Institut Teknologi Sepuluh Nopember

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APPROVAL FORM II

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ABSTRACT

The need for electrification in Indonesia has increased significantly by facing several obstacles in the production of electricity. In facing these production constraints, the government of the Republic of Indonesia has a plan to accommodate problems with several energy production project developments. Precisely in Southeast Sulawesi, market demand has increased with the planned development of the smelter and mining industry in the coming years. Electricity production planning that is built in accordance with the PLN RUPTL is to accommodate the demand for electrical energy by creating a Mobile Power Plant, one of which is the Barge Mounted Power Plant. The Barge Mounted Power Plant (BMPP) uses dual fuel and is a power plant that has the potential for fires in the fuel transfer system from supply to the engine at BMPP. This study analyzes the risks and assesses the dangers that may occur in the fuel transfer process using the Hazard and Operability Studies (HAZOP) method. HAZOP analysis then gets the identification of hazards that exist in the entire system, namely jet fire, flash fire, vapor cloud explosion and gas dispersion. The hazards that have been identified are then categorized in the node system and analyzed quantitatively using Fault Tree Analysis and Event Tree Analysis. Possible hazards were also analyzed by Fire Modeling using ALOHA software. The results of ETA and FTA and Fire Modeling software are assessed by the FN Curve method, the assessment results show that almost all nodes in each scenario enter into the ALARP condition. The author makes recommendations on the Layer of Protection Analysis (LOPA) by adding several instruments to prevent the occurrence of fires such as; Heat Detector Alarm, Pressure Alarm and Gas Detector Alarm. These additions need to incur costs, so in the recommendation by considering IMO, the authors present the results of an economic analysis with a picture of Gross Cost Converted Fatalities (GCAF) with acceptance criteria of 1M \$. So there are some unacceptable case scenarios such as, case 6 in VCE and Flash Fire and case 2 and case 6 in Jet fire.

Keyword: Risk assessment, Hierarchical Modeling, FN Curve

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ABSTRAK

Kebutuhan elektrifikasi di Indonesia kian meningkat signifikan dengan menghadapi beberapa kendala produksi energi listrik. Dalam menghadapi kendala produksi tersebut, pemerintah Negara Republik Indonesia memiliki rencana untuk mengakomodir permasalahan-permasalahan dengan beberapa pengembangan proyek produksi energi. Tepatnya di Sulawesi Tenggara, permintaan pasar meningkat dengan adanya rencana pembangunan industri smelter serta tambang pada beberapa tahun mendatang. Perencanaan produksi energi listrik yang dibangun sesuai dengan RUPTL PLN adalah dengan mengakomodir permintaan energi listrik dengan membuat Mobile Power Plant yang salah satunya adalah Barge Mounted Power Plant. Barge Mounted Power Plant (BMPP) menggunakan dua jenis bahan bakar dan merupakan pembangkit listrik yang memiliki potensi-potensi terjadinya kebakaran pada sistem transfer bahan bakar dari supply ke mesin pada BMPP. Penelitian ini menganalisis risiko serta menilai bahaya yang mungkin terjadi pada proses transfer bahan bakar menggunakan metode Hazard and Operability Studies (HAZOP). Analisis HAZOP kemudian mendapatkan identifikasi bahaya yang ada pada seluruh sistem yaitu jet fire, flash fire, vapour cloud explosion serta gas dispersion. Bahaya yang telah diidentifikasi kemudian dikategorikan dalam sistem node dan dianalisis secara kuantitatif menggunakan Fault Tree Analysis dan Event Tree Analysis. Bahaya yang mungkin terjadi juga dianalisis dengan Fire Modeling menggunakan software ALOHA. Hasil dari ETA dan FTA serta Fire Modeling software dinilai dengan metode FN Curve, hasil penilaian menunjukan hampir seluruh node pada tiap-tiap skenario masuk kedalam kondisi ALARP. Penulis membuat rekomendasi pada Layer of Protection Analysis (LOPA) dengan menambahkan beberapa instrumen pencegahan terjadinya pancaran api seperti; Heat Detector Alarm, Pressure Alarm serta Gas Detector Alarm. Penambahan ini perlu mengeluarkan biaya, sehingga dalam rekomendasi dengan mempertimbangkan IMO, penulis menyampaikan hasil analisis secara ekonomi dengan gambaran Gross Cost Averted Fatalities (GCAF) dengan acceptance kriteria 1M$. Sehingga didapatkan beberapa case skenario yang tidak dapat diterima seperti, case 6 pada VCE dan Flash Fire serta case 2 dan case 6 pada kondisi Jet fire.

Kata Kunci: Risk Assessment, Hierarchical Modeling, FN Curve

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PREFACE

The author gave thanks and praise to the Almighty God, Allah SWT and also Prophet Muhammad saw who has given me strength and wisdom so that the author can complete his studies and this bachelor thesis. Hopefully with the completion of this research study, authors gain more perspectives, information, and knowledge for the future career. The author owed sincere and earnest appreciation for those who had helped, guided through and provided the author vital suggestion in the completion of this bachelor thesis.

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11. Colleague of Himasiskal FTK-ITS
12. Fellow colleague the author who always there in bitter sweet conditions

The author concerns for the imperfection in this thesis. Therefore, any criticism and suggestion are expected. The author hoped this thesis will provide benefits primarily for the readers.

Surabaya, 2020

Hadyan Rahman Luhuri Putra

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TABLE OF CONTENT

LIST OF FIGURE

"Halaman ini sengaja dikosongkan"

LIST OF TABLE

"Halaman ini sengaja dikosongkan"

CHAPTER I
INTRODUCTION

1.1 Background

Indonesia is a vast country with so many islands, the country's development in various sectors faces a variety of problems from infrastructure to superstructure. One of the developments to find prosperity for the people of Indonesia is the equitable supply of energy to all corners of the country. Electrification is a development that is often vital to be the cornerstone of development in other sectors. Indonesia's electrification has increased quite high when viewed from the 2017 Electrification Ratio published by the official website of the Ministry of Energy and Mineral Resources. According to estimates from the site, Indonesia's electrification ratio has always increased since 2010. Until the achievement of the realization of Indonesia's electrification in 2017 it reached 95.4% nationally. The regions with the lowest electrification ratio in 2017 were West Nusa Tenggara with a ratio of 59.85% and Papua with a ratio of 61.42%. Projections from the 2017 electrification ratio data in 2018 Indonesia will have an electrification ratio of 97.5% and in 2019 have an electrification ratio of up to 99%.

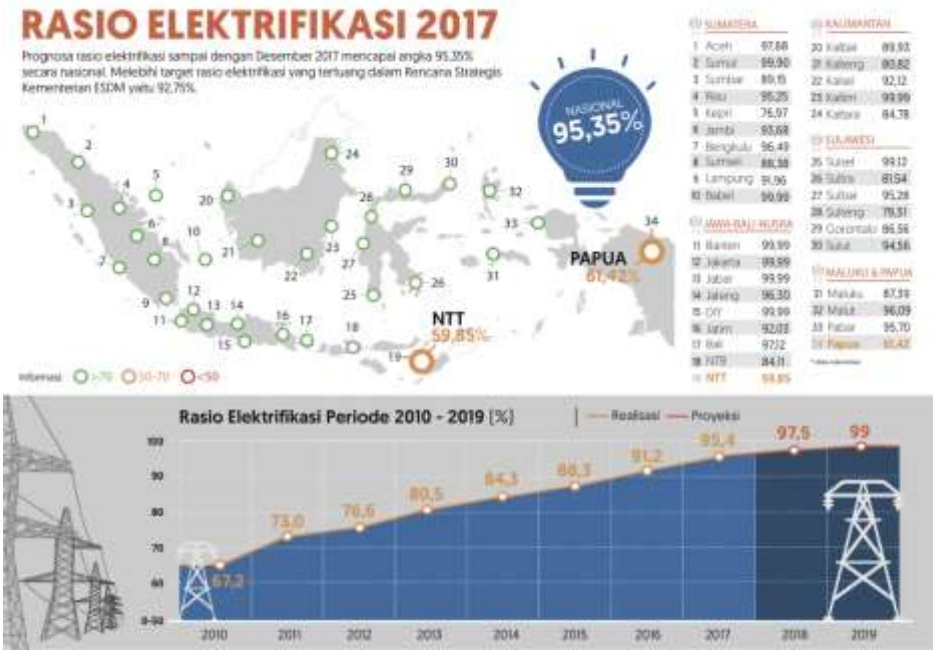

Figure 1.1 Electrification Target of Indonesia
(Source: RUPTL PLN 2018-2028)

The demand on electrification in Indonesia had to be taken seriously and prevent any obstacles from the infrastructure of electricity supplier in which is a power plant. Certain of South East Sulawesi power plant is still under construction but the demand would keep raisen. Preventing the losses of this condition, Indonesian company in which objective is to fulfill the electrification of Indonesia take the technology of Mobile Power Plant.

Figure 1.2 Barge Mounted Power Plant Visualization
(Source: www.pal.co.id)

But as we obtain that every power plant has a risk to take even if it was a prevention action of an obstacle remain. Reporting from Antara news article, development data in the electricity sector has a variety of risks that may occur and inhibit or harm the stakeholders. The incident in Sepang Bay, Bengkulu City on Tuesday 9 July 2019 became one of the events that needed to be prevented before causing an accident that claimed lives. In the 2 x 100 Mega Watt Coal Fired Power Plant, two victims died, one of whom died.

The accident also occurred on July 11, 2019 at the Gas Power Plant (PLTG) in Moscow, Russia. The fire that broke out at the Mytishchi TET-27 power plant left one person dead and dozens injured. The power plant has been operating since 1992 with a total capacity of 1068 MW with the main fuel using natural gas used to flow electricity for the northern part of Moscow. Fire is estimated to reach 50 meters into the air with a blaze area of up to 800 square meters. According to reports, 70 fire-fighting units were deployed to cope with the incident. (Franki,2019)

Figure 1.3 PLTG Moskow Fire Accident
(Source: www.listrikindonesia.com)

It is necessary to implement a system that deals with fire prevention in order to minimize fire victims, in this case, the development of a risk analysis system has evolved since it was first announced in 1979 by KK Aggarwal who discovered the synthesis of reliability relationships to be modeled in a simple algorithm to obtain the value of a risk analysis. Until now the application of risk analysis using Fault Tree Analysis has grown rapidly to be able to use a computer automation system that can analyze systems with high complexity. In risk assessment using HAZOP or hazard identification with quantitative analysis, several methods are needed to prioritize the assessment to determine risk priorities. The priority of risks with the highest hazard according to expert judgment will be the standard as an object that will be assessed as a representation of other hazard risk conditions. Therefore, risk assessment by taking a quality analysis in advance will be difficult to be able to assess risk with a low priority value until it cannot evaluate risk without a priority value. Risk assessment by prioritizing qualitative assessment is very dependent on the justification of experts so that there is a risk of biased assessment of human subjectivity. (Rausand and Heyland, 2016)

So at this time, the risk assessment scheme is created without using quantitative analysis, but instead assumes that every hazard that can emerge has the same priority value. This application can be used on systems that have high complexity with examples of three vertical segmentations in the system. The system is reduced to the smallest set by reducing the parameters of the sub-system to make groups of units with more basic parameters. The risk assessment is then obtained by minimizing the assessment of bias from humans and prioritizing the process of cause and effect occurrence of each event until the fundamental events that can be compiled and concluded by combining each segmentation with parameters at the horizontal system level.

1.2 Problem Identification

Formulation of the problem in research:

1. How to determine the potential dangers that can occur in the process of fuel transfer at the Barge Mounted Power Plant?
2. How to determine the assessment of the potential hazards that occur in the fuel transfer process calculated in quantitative mode?
3. How to determine value of the consequences of a possible accident to the crew of the Barge Mounted Power Plant?
4. How to propose the mitigation recommendations from the results of the fire risk analysis on the Floating Power Plant?

1.3 Research Limitation

Research is limited by several aspects:

1. The power plant in question is a power plant on a barge with a capacity of 60 MW
2. The process assessed is the risk of the process of transferring gas fuel from the FSRU to the power plant and diesel fuel tank

1.4 Research Objective

The objective of this study:

1. To determine the potential hazard that occur in the BMPP fuel transfer process
2. To analyze the annual frequency of potential hazards that had been identified in the BMPP fuel transfer process
3. To conduct the consequences of hazard that may occurs in the BMPP fuel transfer process
4. Proposed mitigation as a form of recommendation for the results of fire risk analysis in floating power plants

1.5 Research Benefit

Benefits obtained from this study:

1. As a lesson learning in terms of safety in the field of marine engineering in analyzing the process of fuel transfer at the barge mounted power plant
2. As a consideration of safety in barge mounted power plant with LNG and fuel oil system

CHAPTER II
LITERATURE OVERVIEW

2.1 Oil and Gas Industry of Indonesia

Indonesia has the potential of natural resources that are abundant and become one of the support of citizens ' welfare with one of its aspects is a reserve of petroleum and natural gas that has been commonplace to support the sustainability of Needs of citizens in various modes.

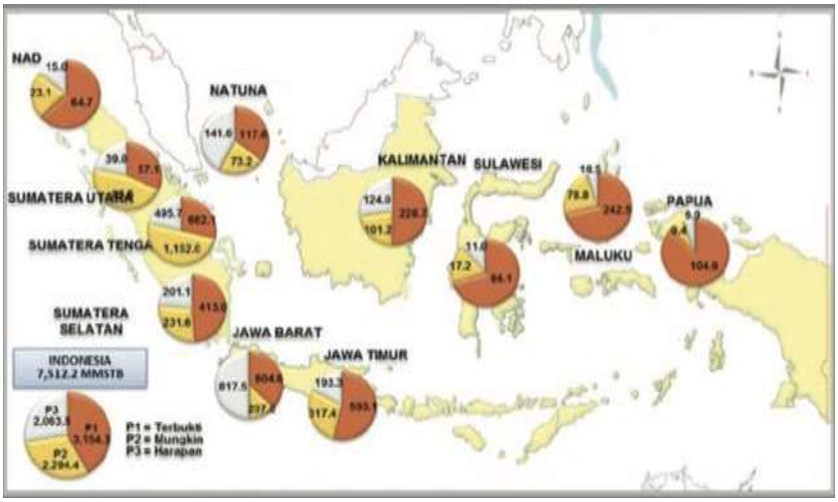

Figure 2. 1 Petroleum Reserves of Indonesia
(Source: esdm.go.id)

However, the industry has not seen significant new developments for a number of years, with many existing contractors having lost interest in further exploration in Indonesia due to regulatory instability and an uncertain investment climate, and few new players are entering the market. Despite the Government's efforts to stimulate exploration through offers of new acreage and a joint study facility, these initial incentives have not been particularly successful in attracting new investors. Knowing the potential, Indonesia has been conducting exploration and exploitation of existing natural resources and to be able to process it to be processed to-in-industry from upstream to downstream. Simplify the mapping data obtained from the results of the exploration, Indonesian national standard through SNI 13-4726-1998/AMD 1:1999 made guidance on the classification of mineral resources and reserves. The chart mapping of petroleum and natural gas deposits included by the Ministry of Energy and Mineral resources, the classification in the charts is drawn to several aspects, namely:

1. Proven reserves, which is a measured mineral resource based on mine feasibility studies all related factors have been fulfilled, so that mining can be done in an economical manner.

2. Significant reserves, which are the designated mineral resources and some measured mineral resources, are still lower in their geological beliefs, based on mine feasibility studies all related factors have been fulfilled, so that Mining can be done in an economical.

Figure 2.1 shows the chart of the petroleum reserves in Indonesia that have been mapped based on the source of petroleum sources. The picture shows the classification and number of Indonesian petroleum reserves which have proven 3154.3 MMSTB reserves and potential reserves of 4358 MMSTB. The number of mappings with the graph is mapped in geographic with the number of oil reserves located in the Land field of 2186.62 MMSTB (or 68.96%) And the remaining 984.26 MMSTB (31.04%) In the ocean.

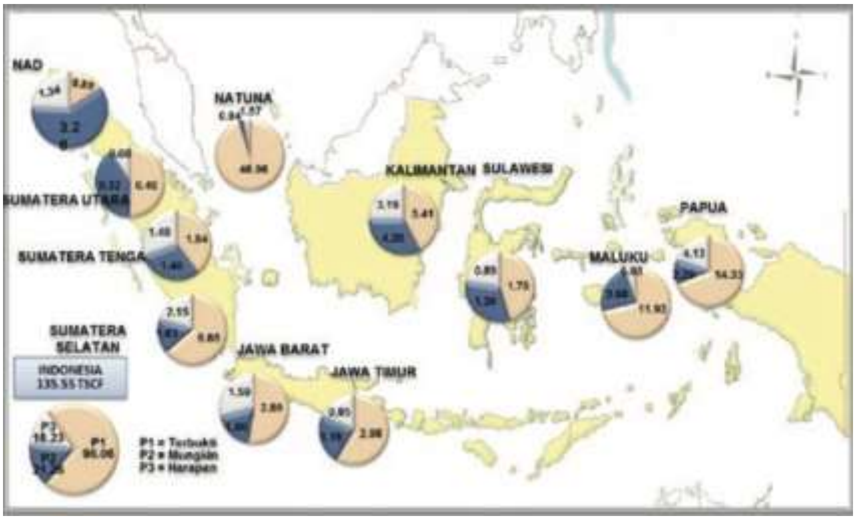

Figure 2. 2 Natural Gas Reserves of Indonesia
(Source: esdm.go.id)

Figure 2.2 shows the graph of the Indonesian gas reserves that have been mapped based on the land source of the natural gas. The picture shows the classification and number of Indonesian gas reserves with a proven reserve of 99.06 TSCF (Trillions of standard cubic feet of gas. Equivalent to 1,000,000,000,000 standard cubic feet) and a potential reserve of 39.49 TSCF. The number of mappings with the graph is mapped further based on the geological conditions of the natural gas source, the Associated Gas (gas found in conjunction with petroleum at one reservoir) totalling 3857.8 TSCF, and the Non-Associated Gas (natural gas Total) amounting to 92199.7 TSCF.

The image shows measurements on the natural gas reserves using the Standard Cubic Foot depicting the amount of gas required to fill the room with a cubic foot size of approximately 14.7 psi and at a temperature of 60 degrees Farenheit is in dry condition.

2.3.1. Liquefied Natural Gas

Natural gas is a fossil fuel, LNG made from organic material that is absorbed and buried in the earth for a million years ago. LNG is a fossil fuel called "hydrocarbons" because it has carbon and hydrogen content in it. LNG has a mixture of methane, ethane, propane and butane with a slight capacity of more heavy hydrocarbons.

Table 2. 1 Typical Chemical Composition of LNG
(Source: Center for Energy Economics)

Chemical	Chemical Formula	Low	High
Methane	CH_4	87%	99%
Ethane	C_2H_6	<1%	10%
Propane	C_2H_8	>1%	5%
Butane	C_4H_{10}	>1%	>1%
Nitrogen	N_2	0.1%	1%
Other Hydrocarbons	Various	Trace	Trace

The most widely contained component in LNG is Metana which has very low boiling point until LNG is referred to as cryogenic fluid, or it can be called as fluid that has a very low boiling point that is below-100 o C. When compared to LPG that has the greatest content is propylene and has a much different properties than LNG. The nature of propane is easier to reach the boiling point is at-43 O.

2.2 Power Plant

Power plant is a tool that can produce and generate electrical power by changing certain energy. Power plant is now grouped into several kinds according to energy that is converted into electrical energy, power plant is now developed in Indonesia to become hydroelectric power, steam power plant, power plant Gas power, steam power plant, Diesel power plant and Gas engine power plant.

The Indonesian power plant is fully managed by the Perusahaan Listrik Negara (PLN) which guarantees and pursues national electrification achievement. The case study will be taken to research this time promoting supporters who can become solutions to electrification in difficult areas of land infrastructure with floating technology that uses Pembangkit Listrik Diesel Gas (PLTDG).

Figure 2. 3 PT. PP (Persero) TBK PLTDG Pesanggaran
(Source: pt-pp.com)

2.2.1 Barge Mounted Power Plant

Barge Mounted Power Plant innovations carried out by optimizing the space and mobility of sea transportation modes as a support for national electrification. Barge or Barge is modified to become a container for a power plant that the provisions of the generator are adjusted to the needs.

Reporting from the Electricity Supply Business Plan of PT. State Electric Company (Persero) in 2018 until 2027 which has been approved by the Decree of the Minister of Energy and Mineral Resources of the Republic of Indonesia number 1567 K / 21 / MEM / 2018 states that:

1. Procurement of mobile power plants (barge mounted or truck mounted) with dual fuel fuel (gas and fuel) with a view to:
    - Overcoming power supply shortages due to delays in generating or transmission projects.
    - Reducing rent for oil-fired generators.
    - Electrifying areas that do not yet have electricity supply and increasing electrification ratios.
    - Meet the growing demand.
    - Overcoming the lack of power supply due to the release of existing generating units both due to interference and maintenance.

2. Procurement of mobile power plants (barge mounted or truck mounted) with dual fuel (BBM and gas) has indispensable benefits, namely:
    - Meet the growing demand.
    - Reducing rent for oil-fired generators.
    - Overcoming power supply shortages due to delays in generating or transmission projects.

  - Overcoming the lack of power supply due to the release of existing generating units both due to interference and maintenance.
  - Meeting temporary demands due to major events (national or international).
  - Electrifying regions and communities that have not yet received electricity supply (increased electrification ratio).
3. The Mobile Power Plant is divided into several developments including barge mounted, truck mounted and container
  - Truck mounted, used as a support for areas with relatively small electricity supply needs and has adequate land infrastructure.
  - Container, used as a support in the mainland which requires a relatively small electricity supply.

In accordance to Bruce W. Gerhold in 2004 the flow of dual fuel generation system claimed as it would picture:

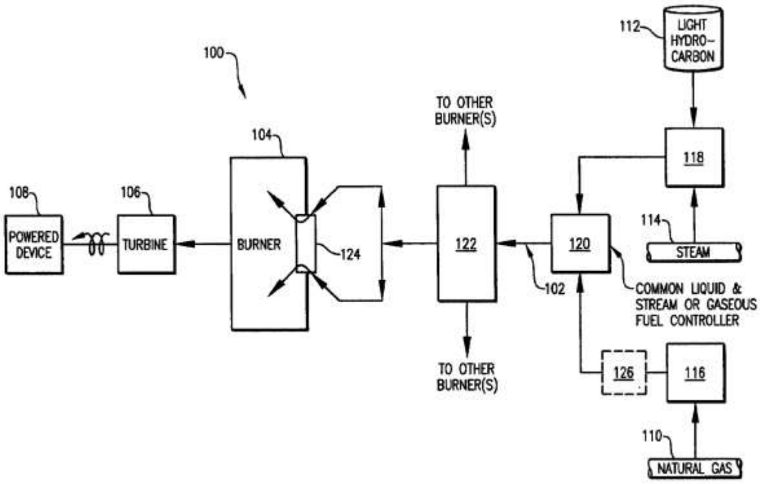

Figure 2. 4 Flow of Dual Fuel Generation System
(Source: ConocoPhillips Company)

In the system flow described by number would be defined as :

- 112, as a fuel source in the system
- 118, metering/blending device
- 114, described as steam source
- 116, gaseous fuel exiting gas metering device
- 120, fuel controller
- 122, fuel distribution system
- 124, defined as nozzle
- 104, described as burner
- 106, defined as turbine
- 108, as a powered device

2.3.2. Ship to Ship LNG Transfer

In accordance to "Peraturan Pemerintah Republik Indonesia No.82 Tahun 1999 Tentang Angkutan di Perairan, Pasal 44 ayat (1) Ship to Ship Transfer adalah kegiatan pemindahan langsung muatan gas, cair, ataupun padat dari suatu kapal ke kapal lainnya." (Yolanda,2017).

Operating vessel to transfer load would have to remain station or depend on the circumstances of operating factor to be calculated in weather and sea condition. In General, ship to ship transfer has four phases to be determined (Stavrou & Ventikos, 2014) such as:

1. Preparation
2. Mooring
3. Cargo Transfer
4. Unmooring

Figure 2. 5 The Bunkering of LNG Cargo
(Source: marine-executive.com)

2.3.3. Location of BMPP

The natural potential which is rich in nickel reserves in the Southeast Sulawesi region encourages local economic growth, besides that the fisheries sector has the potential to increase significantly.

Based on the Electricity Supply Business Plan of PT. PLN (Persero) in 2018 - 2027, economic growth in the province increased quite high in recent times with an average growth of 7.35% per year. Economic growth was also accompanied by an average 12.7% growth in electricity consumption. The highest electricity consumption ratio is used for household electricity usage with a percentage in 2016 of 67%.

The Electricity Demand Projection Table from 2018 to 2027 is mapped into several aspects of growth on the basis of Economic Growth with which aspects of economic growth are represented in the presentation of electricity sales, production, peak load to customer estimates of electricity.

Possible mooring locations with geographical and supporting infrastructure are found in North Kolaka in Waliho village. The infrastructure in question is the existence of a land cable line that connects several villages directly from the coast and has a voltage of 150kV.

Figure 2. 6 Sea Depth of Kolaka Utara
(Source: Navionics.com)

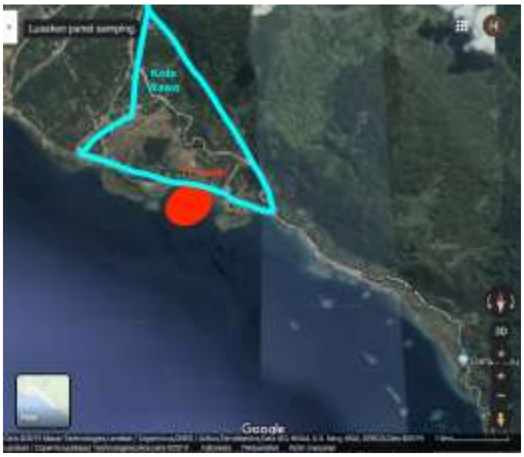

Figure 2. 7 Kolaka Utara Map
(Source: gmaps.com)

2.3 Fire

Fire is one of the disasters or hazards that can arise around human life environment that may occur because of human action or naturally occurring. Fire is an event where fires burn objects around it without being controllable, where fire is a chemical chain reaction known as burning.

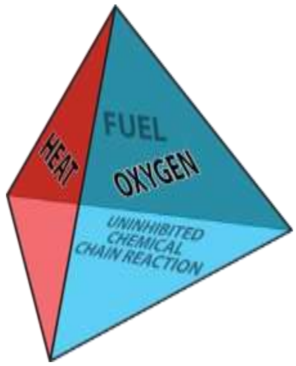

Figure 2. 8 Tetrahedron of Fire
(Source: Guides.co)

David T. Gold: Combustion is a rapid oxidation process that generally generates heat and flame. Fire can be formed by assimilation of several aspects, namely fuel, heat, chemical reactions and heat, and the aspect of these aspects is presented as Tetahedron of Fire.

Fires begin with the most crucial stages of fire in the room. The process of emergence is caused by thermal energy. The emergence of fire is also caused by components of the tetrahedron fire joining together forming a reaction. Once there is a flame and no follow-up from the starting stage will then enter the stage of growth where the increase of the flame. The process of flame growth can spread rapidly with conduction process, convection and radiation. Entering the full combustion stage where the heat released by the flame enters the greatest stage that can cause a malfunction. If the fire has already occurred and the burnt material has started to run out, it will enter the receding stage where the fire slowly disappears. The following types of fires may arise.

- Jet Fire, this type of jet fire will be caused by leakage in the gas accompanied by the ignition of the flame directly. The possibility of jet fire is when the gas is in the liquid and low-pressure phase. Fire T fire type can generally occur in gas transfer process that has become liquid phase. Generally, jet fire has a heat transfer rate above 200 kW/m2. The damage caused by jet fire has a serious level of damage.
- Flash Fire, a gas leak that is not accompanied by flame ignition is the main cause of the Flash fire. The characteristics of the occurrence of flash fire generally have high temperature and short time duration.
- Boiling Liquid Expanding Vapor Explosion (BLEVE), Boiling Liquid Expanding Vapor Explosion (BLEVE) is one type of explosion that occurs due to pressure on a vessel ruptured or leaked due to heat impact from the outside of

the vessel. This accident can also occur when a vessel that contains fluid passes the boiling point of the liquid. The biggest impact that BLEVE can result from is the resulting radiation.

- Gas Dispersion can be caused by gas leakage in the pipeline or other components. This work accident may occur if the gas condition flows under high pressure conditions. Damage caused by gas dispersion generally affects human health because the oxygen content is contaminated with gas leakage occurring.

2.3.1. Hazard and Operability Study

Identifications of problem in the operational process in any system would affect the efficiency and safety of system. HAZOP identified the deffect in system from normal condition, it defined as some terminology the identification process, in which:

- Deviation, called as a combination keyword to be applied (the word guide and parameters combination).
- Cause, deviation created by cause which was described as some process
- Consequence, an effect represented by loss of an event
- Safeguards, prevention of the cause, or a protection against the consequences of loss.
- Action, if a cause of an event could be described to have a negative consequence, we should look up to any behavior to be done as counted in action. Action should be separated into two purpose, to reduce cause of an event or to clear up the consequences. Oftenly, action would be prioritized to reduce the cause of an event that could decreaase the consequence automatically.
- Node, described as a segmentation of unit process to become a few of study limit. Segmentation of unit would made study of process to be at ease.
- Severity, described as how priority of critical level that estimated to happen.
- Likelihood, described as potential consequences in condition with safeguard
- Risk is a potential of loss in some event

2.3.2. Hierarchical Modeling

Howard B Degenholtz. Mamta Bhatnagar, 2009. Hierarchical Modeling has been used for analysis of secondary data, performance profiles or benchmarking studies, and in prospective trials. The technique is used in situations in which traditional regression analysis might lead to incorrect conclusions. Specifically, data drawn from nested settings such as hospital units or hospice providers may be correlated, thus violating an assumption required for ordinary least squares regression. When used appropriately, HM allows researchers to specify and test hypotheses that would not otherwise be possible, and avoid incorrect conclusions from nested data.

HM had three common hierarchical model which was separated by the construction of graph.

a. Classical Linear Model
b. Random Intercept Model
c. Random Intercept and Slope Model

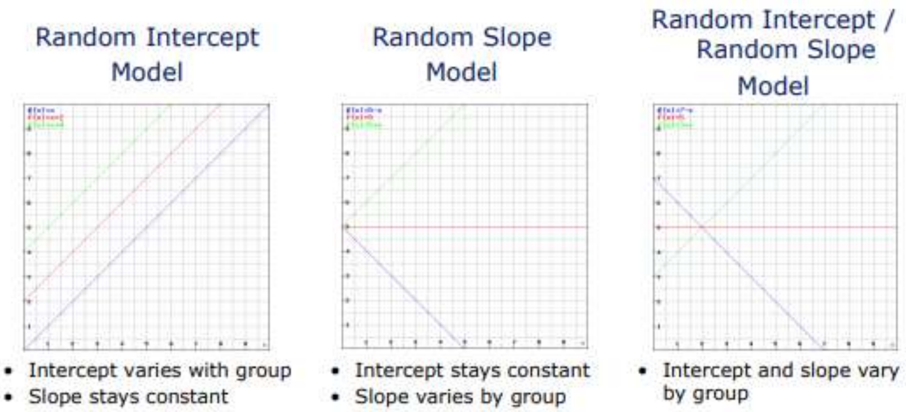

Figure 2. 9 Three Common Hierarchical Model Graph
(Source: Journal of Palliative Medicine)

2.3.3. Fault Tree Analysis

Fault Tree analysis is a versatile tool that quickly wins the liver with those involved in the calculation of reliability and security. But the fault tree model has weaknesses. Techniques such as tree analysis errors should be applied. Fault Tree analysis can efficiently redirect analyst efforts in considering only basic events that can contribute to system failures and represent human error relationships and environmental conditions in causing failures System. With the rapid advancement of automated fault tree analysis, this technique can be a more effective and sophisticated analytical reliability tool.

The main difficulty with a quantitative fault tree evaluation (as well as quantitative reliability techniques) is the lack of data related failure rates. However, quantitative evaluation is invaluable for comparing system designs that have similar components.

The results are not sensitive to failure rate data such as absolute determination of the probability of system failures. Due to the uncertainty in the data failure rate, the quantitative fault tree analysis has the greatest value when the relative determination rather than absolute is made. The analysis of the Fault Tree is then best applied during detailed design stages of the system.

Fault Tree Analysis first appeared in 1961 by H. A. Watson from Bell Telephone Laboratories at the time of filing a contract with the United States Air Force to study missile launch control system.

Analysis of fundamental tree error analysis of the translation of the physical system into a diagram of structured logic (fault), in which certain cases are determined to be a reference to the TOP analysis. This log Diagram is constructed using the image symbol and the image symbol in Figure 1.

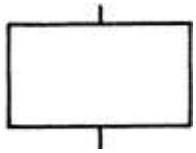

Figure 2. 10 The Square
(Source: IEEE Transaction on Reliability)

A rectangular symbol identifies the events of some possible combinations of events with the input gate.

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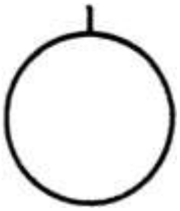


Figure 2. 11 The Circle
((Source: IEEE Transaction on Reliability)

The circular symbol describes the simplest conditions of a possible event so that no development is needed afterwards. The frequency and failure modes of an item with this symbol identified are derived from the empirical data.

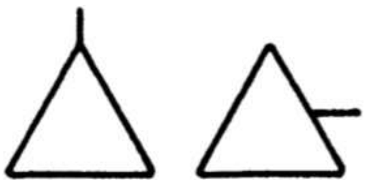


Figure 2. 12 The Triangle
(Source: IEEE Transaction on Reliability)

The triangle is used as a transfer symbol. The placement of lines next to or below the triangle indicates outbound transfers.

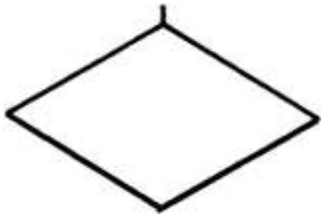


Figure 2. 13 The Diamond
(Source: IEEE Transaction on Reliability)

The diamond symbol describes the event of an error that is considered basic in the given fault tree. Possible causes of the event are not developed further because the event is not quite a consequence or the required information is unavailable.

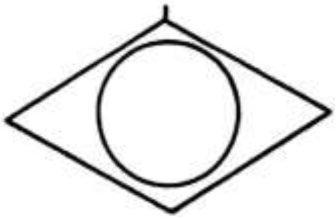


Figure 2. 14 The Circle within Diamond
(Source: IEEE Transaction on Reliability)

The circlen within diamond symbol that the subtree exists, but the subtree is evaluated separately and the quantitative result is inserted as if the component.

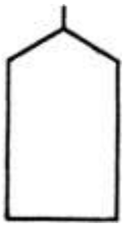


Figure 2. 15 The House
(Source: IEEE Transaction on Reliability)

The house symbol is used as a switch to insert or remove parts of a fault tree because parts of it may or may not apply to certain situations.

Logic Operations Symbols:

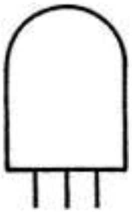


Figure 2. 16 The AND Gate
(Source: IEEE Transaction on Reliability)

The AND Gate describes a logical operation where the harmonious relationship of all input events is required to generate output events.

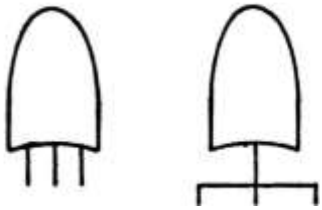


Figure 2. 17 The OR Gate
(Source: IEEE Transaction on Reliability)

The OR gate is defined as a symbol to declare a situation where the state of the output will be formed when there is one or more input events.

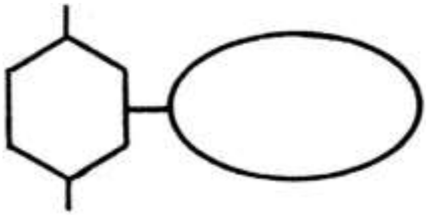


Figure 2. 18 The Inhibit Gate
(Source: IEEE Transaction on Reliability)

The gate barrier is a casual relationship between one mistake and the other. Direct Input generates output if the indicated condition is met. The custom Input defines a system state that allows the sequence of errors to occur, and may be normal for system or result form failures.

Fault Tree Analysis can be done in four phases of work, starting from defining the system being analyzed, then with the function definition to the foundation of the system, then construction to make analysis can be made, by defining component components and placing them in accordance with the system hierarchy. Fault Tree Analysis is intended to obtain the results of the analysis of researchers to be able to find the source of events that are rooted in various kinds of events from the working principle of the tool in the system or the relationship system itself.

After the definition of the component, which describes the system in detail or overall, qualitative and quantitative evaluation can be performed. In aerospace, the more general term "system failure condition" is used for the "undesired state" / top event of the fault tree. These conditions are classified by the severity of their effects. The most severe conditions require the most extensive fault tree analysis.

2.3.3.1 System Definitions

The Fault Tree Analysis starts with an unwanted event statement, for example, a system failure. Analysis with three basic types generally requires a few things, as follows:

1. Operation Mode and component failure: A description of how the output status of each component is affected by the input status of each component affected by the input status and internal operating Mode of that component.

2. System Chart: A description of how the components are interconnected. The system functional layout diagram should demonstrate all the functional interconnections and identify each component.

3. System boundary Conditions: This determines the situation in which the fault tree should be drawn. The top event, the initial condition of an existing event or is not allowed, and the top of the tree is a system boundary condition.

2.3.3.2 Fault Tree Construction

Fault Tree Construction is a fairly complex and complex program that involves data from all over the system to the components. Research that has been made with the help of computers is one of the solutions that draws attention to there are some researchers who can be classified to understand the Fault Tree construction technique.

1. David HAASL compiled a guide to determine the types of gates to be used for the input gate.
2. J.B. Fussel introduced the manufacture of Synthetic Tree Model (STM) by representing the component in the structure into computer code and automatic so that it is widely used to analyze the electrical system. Fussel introduces a failure transfer function which is then traced through this scheme, function, transfer for various components combined and edited to form a Fault Tree.
3. Powers & Tompkins Use an automated Fault Tree method to analyze the chemical system. The analysis starts by linking the causal variable between elements and then pairing them up to forming the Fault Tree.
4. Salem, Apostolakis, Okrent, form a Computer Automated Tree (CAT) system code. CAT defines the system and makes it automated on computer systems implemented by researchers on nuclear modelling and various complex modelling involving mechanical, electrical, hydraulic, and human interactions systematics.
5. Lapp & Powers Fault Tree Synthesis Program (FTS) uses methods by creating Diagraf (directional graphs) that represent functions on the system and analyzes failures through system components.
6. Camarda et Alii proposes an algorithm that can determine the synthesis of From Fault Tree using reliability graphs on large systems.

7. Taylor & Hollo uses an algebraic noun to create a Cause Consequence Diagram (CCD). CCD is also a comprehensive method of detail, as it can define the sequential and chain effects that occur afterwards.

2.3.3.3 Quantitative Evaluation

The first step in a quantitative evaluation of the Fault Tree is to find a structural representation of the top event in terms of basic events. Finding a set of minimal pieces is one way to achieve this step. If the incidence rate and duration of errors for all basic occurrences are known, and the statistical dependency of any underlying event is known (or assumed), then the statistical expectations or probability of peak events can be determined.

Minimum set of pieces and set of S-coherent fault tree paths can be obtained by using one of the available codes. System unavailability can then be calculated: 1) precisely by using the minimal set cut/set path to write tree structure functions as the number of products from the underlying events provided the underlying events are not replicated in the set cut and all events Independent statistical basis; or 2) approximately, using one of the following standard methods:

a. Method of exclusion of inclusion to find the upper and lower limits in a row
b. With the top event probability.
c. Minimum cut upper and lower limit min line when the basic event is statistically independent.
d. The minimum limit for a statistically dependent base event is a basic related event.

The size of the importance of the incident and the cut set on Fault Tree are another important feature of quantitative analysis. While event evaluation at the top of the chain provides information on system reliability/availability, calculations of probabilistic interests can result in numerical ratings to assess weaknesses in a system

2.3.4. F-N Curve

In representing the value of the frequency and the value of the consequences gained from the simulation and calculation, there needs to be a standard of conformity through standardization. The standard taken this time is from the UK Offshore, which has one method of using a standard chart with a graphical methodology of the F-N curve. The F-N build graph is made with parameters between the frequency denoted by (F) and the number obtained from the modelling of the victim which may be caused by denoted (N).

A simplified representation in the form of F-N Curve in social risk has three important instruments that determine whether or not an assessment of risk is received, including:

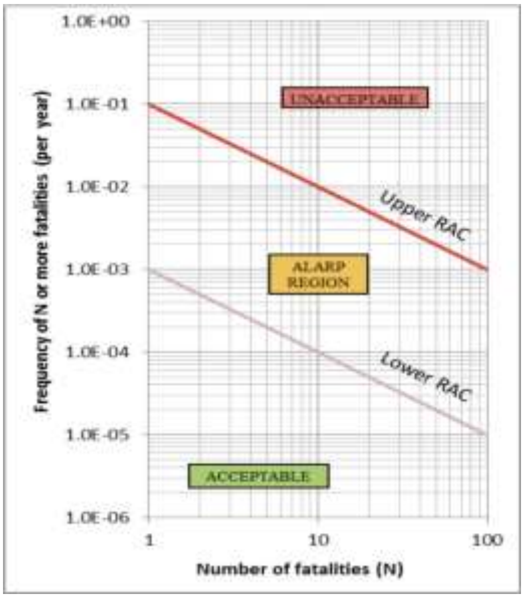


Figure 2. 19 f-N Curve
(Source: Europa.eu)

2. Acceptable

   The risks in the sections contained in this category are depicted as the risks in which impact is acceptable. When risks exist in this category, risk is considered not to be given to mitigate risk, except with practical and very simple actions depicted with low cost countermeasures, little time and effort Simple.

3. ALARP

   As Low As Reasonably Practicable describes a risk condition in this category has the most critical tolerance as a condition that is still tolerable. Risks in this condition can be tolerated with an impractical countermeasures if the cost of countermeasures is disproportionate to the level of risk to improvement that can be obtained.

4. Intolerable

   The condition of the Risikop value in this category is described at a risk that is not tolerable. The overview of tolerance in these risk cases depends on the assessment of the risk value e.g. social risk with the impact social victims are already unacceptable.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Flow Chart

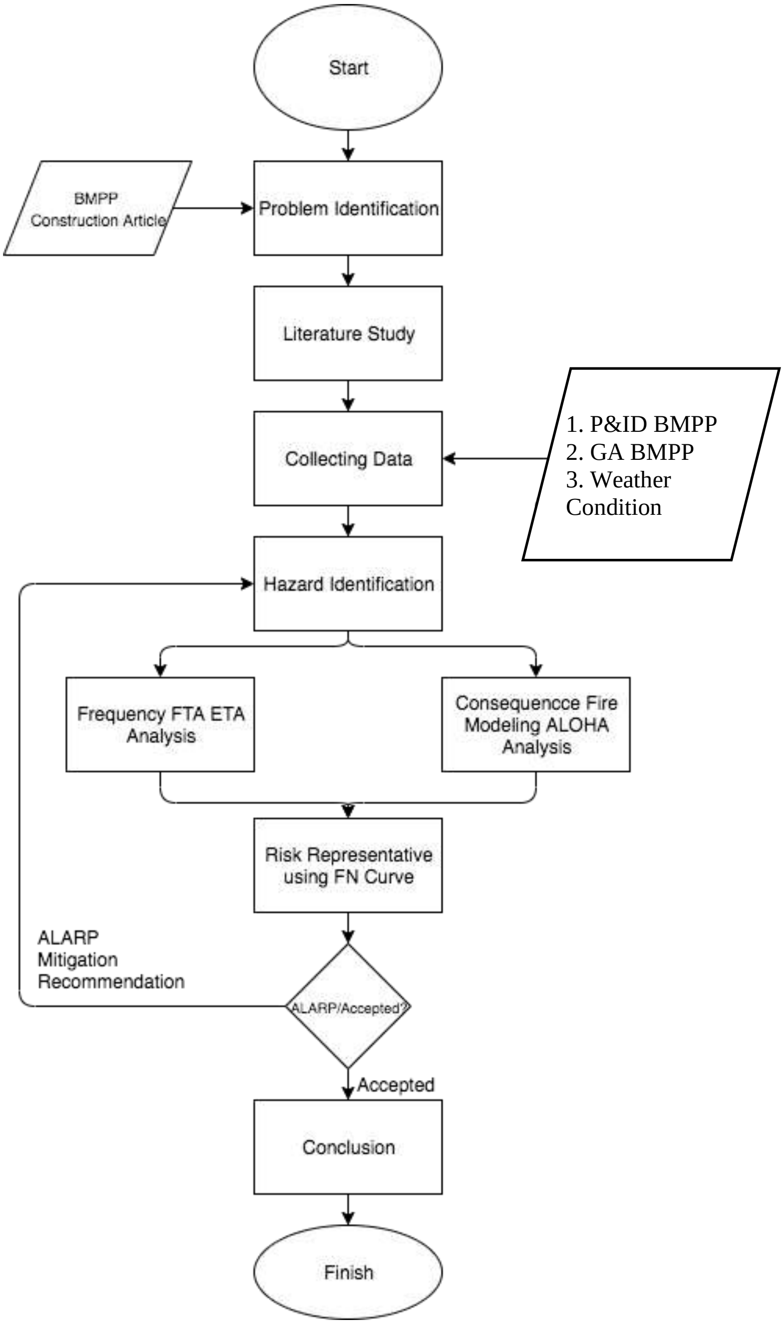


Figure 3. 1 Flow Chart

3.2 Research Methodology

Research Methodology is the basic framework of a study that includes all activities carried out to solve a problem with the stages that have been prepared, such as the study of literature, methods, validation and conclusions

3.3 Problem Identification

The formulation of the problem is the initial stage in the implementation of the thesis. This stage is a very important stage, where at this stage why an existing problem must be solved so that it is feasible to be used as material in the thesis. Search for problems is done by digging information about the problems that occur at this time. From this stage also, the purpose of why this thesis is done can be known.

As we identificate the performance of Indonesian company to perform electrification in Indonesia, we should accomodate the initial prevention of fire accident that counted as societal risk.

From the identification of problem, then research should determine to be risk assessment on BMPP as the risk of fire accident.

3.4 Literature Study

After a problem is known, then the next is literature study. Where should be done at this stage, is to look for references to the problems that exist along with the solution and also study both of them to be implemented in this thesis, so it is clear what needs to be done so that the problem can be solved. Literature study can be done by bringing papers or journals related to the problem to be solved.

BMPP - Hazard Identification Literature Study - Consequence Literature Study - Frequency Literature Study - Risk Assessment Method Evaluation - Hierarchical Modeling Concept – LOPA.

3.5 Hazard Identification

Identification process of this research shall contain these certain orders:

- Understand the overall system of fuel consume in BMPP
- Define each system to conduct nodes
- identificate deviation on node
- identificate cause and consequence
- determine safeguard
- determine action required

3.6 Hierarchical Modeling

Determining sub-systems in risk assessment research, needs to be pursed or chosen which system to assess. In this method, sub-systems are created by separating the whole system in several sub-systems by creating parameters that determine the difference between sub-systems from one another.

Based on the research Byoung Jeong,2017, sub-system parameter in fuel transfer system should be divided into system location and operating hours.

Separate the system of BMPP Fuel Transfer as

- Natural Gas system that transferred from LNG Vessel
- Diesel Fuel system from Tank in BMPP

Separate each sub-system to:

- Operational Temperature
- Operational Pressure
- Phase of Fuel

Select unit in each subgroup as the minimum set to be analyze in consequence and frequency analysis

3.7 Group Parameter Identification

The whole system is made with a collection of sub-systems that support the achievement of the whole system; the whole sub-system is collected from several groups separated by parameters that are made based on the work units of the instrument to get the lowest set of units. The unit provides output data from some differences that exist with the data based on distinguishing parameters in the group.

3.8 Unit Identification

The unit consists of the lowest working instruments that embody the work of each tool. Unit can show the performance of the tool and the possibility of success for the work of the tool to the possibility of failure.

3.9 Frequency Analysis

Frequency analysis determines the likelihood of a fire by taking modeling data from the likelihood of a fire occurrence. One possible event that could become a fire is a leak in the pipe, created with Event Tree Analysis (ETA). Structure the likelihood of events by taking a pattern that has become the standard likelihood of events from DNV Leak Frequency Datasheets (DNV, 2012).

3.10 Consequence Analysis

Consequence analysis determines the likely impact caused by a fire on the area around the point of fire. In this case the analysis is based on the possible possibilities that can arise from a fuel leak. The leak is represented by several measures of the likelihood of a leak occurring, by taking data from the DNV and calculated through calculations to arrive at a conclusion that a fire area might occur.

3.11 f-N Curve Risk Assessment

The results of the consequence analysis and frequency analysis conducted will determine the likelihood of a fire taking place on the victim based on the data of the inhabited area closest to the unit and referred to as a risk assessment.

The results of the consequence analysis and frequency analysis of the units are then accumulated into a risk assessment of the group consisting of several work instruments or units. The assessment results from the group are then accumulated into subsystems which are then continued into the whole system.

3.12 Mitigation

Mitigation design needs to be done after knowing the results of the risk assessment if it is found the system has potential hazards outside the operating standards that refer to the F-N Curve. The results of the mitigation design carried out by Layer Of Protection Analysis (LOPA) can ensure the protection layer to anticipate the risk of hazards that arise.

3.13 Conclusion and Recommendation

The final step in this research, which is to draw a conclusion from the entire study method that has been done. This conclusion is in the form of the results of the risk assessment which is categorized into the risk category of the f-N curve using the hierarchical modeling method.

CHAPTER IV

BMPP 60 MW SHIP TO SHIP FUEL TRANSFER SCENARIO

4.1 System Configuration

4.1.1 Power Demand in Kolaka

Southeast Sulawesi is a province in Indonesia located in the southeastern part of the island of Sulawesi with the capital Kendari. Southeast Sulawesi was determined as an Autonomous Region based on Perpu No. 2 of 1964 Juncto Law No. 13 of 1964. Southeast Sulawesi is an area that has a fairly large land and islands (38,140 km2). This area has a variety of mining products including asphalt and nickel. Southeast Sulawesi had a population of 2,602,389 people in 2017 with a population growth rate of 2.01% per year.

Among the districts in Southeast Sulawesi Province, there is Kolaka district which will be a highlight in the research because it is the place to implement the 60 MW BMPP. The total population in Kolaka reaches 246,918 people from the Central Statistics Agency of Kolaka in 2016. Kolaka is a district in the province of Southeast Sulawesi with the areas of Kolaka District, Tirawuta District and Batu Putih District. The total area of Kolaka Regency is 3,283.64 m2 and sea waters covering 15,000 km2.

The Kolaka smelter needs as reported by CNBC Indonesia article having a total electricity demand of 350 MW with volt-amps of 412 kVA at optimum conditions. The article also mentions plans to supply electricity with a capacity of 118 MW in 2020.

Table 4. 1 Population in Kolaka
(Source: Badan Pusat Statistik)

South East Sulawesi Population			
Year	Population		Growth (%)
	Province	Kolaka	
2016	2.551.008	246.918	2,06
2017	2.602.389	251.520	2,01
2018	2.653.654	256.827	1,97
2019	2.704.737	261.664	1,93
2020	2.755.589	266.069	1,88

Mining potential is one of the needs of the Kolaka Regency to fulfill the requirements for the sustainability of the industry. The most potential industry in Kolaka is Nickel with a deposit of around 1.3 billion tons which requires mining accommodation with very high electrification needs and can be supported by using BMPP. Smelter is an important component in purifying Ferronickel in Wolo Subdistrict, Kolaka Regency. The Smelter is planned to be launched by CNBC Indonesia, which will have an input capacity of 5 million tons of nickel ore and 230,000 tons of ferronickel output with 22% -24% nickel content per year.


MARKET INVESTMENT NEWS ENTREPRENEUR SYARIAH

Dukung Smelter PT Ceria, PLN Suplai Listrik 412 Juta VA

Realisasi penyaluran tenaga listrik sebesar 412 Juta VA untuk smelter CNI ini akan dilakukan dalam 2 tahap. Tahap pertama sebesar 118 juta VA akan direalisasikan bulan Desember 2020. Tahap kedua sebesar 294 Juta VA akan direalisasikan bulan Desember 2021.

Figure 4. 1 Demand of Electrification Smelter PT. Ceria
(Source: cnbcindonesia.com)

If calculated, we will get electricity needs that must be electrified in 2020 for the smelter company is 100.3 MW with a total power factor measured from the total needs of 350 MW and 412 kVA volt-amps obtained 0.85

While in the 2018-2028 PLN RUPTL the peak load that has been fulfilled for electrification in kolaka is only 168.8 MW which is the accumulated amount of all power plants that have been recorded in the PLN RUPTL.

Table 5. 0-1 Demand in Each City
(Source: RUPTL PLN)

No.	System	Type	Peak Load (MW)
1	Kendari	PLTU/PLTD/PLTG/MG	82,5
2	Lambuya	PLTD	13,4
3	Kolaka	LTD/PLTM	17,4
4	Raha	PLTD	10,1
5	Bau-Bau	PLTD/PLTM	27
6	Wangi-Wangi	PLTD	3,6
7	Lasusua	PLTD/PLTM	7
8	Bombana	PLTD	6,3
9	Ereke	PLTD	1,5

In the South East Sulawesi Electric Power Demand Projection Table in the PLN RUPTL, the peak load requirement in 2020 is 196 MW which when drawn to the existing condition only has 168.8 MW, meaning there is a difference in needs that needs to be met is 27.2 MW.

Table 5. 0-2 Electricity Needs Projection with Economical Growth

Electricity Needs Projection		
Year	Economical Growth (%)	Peak Load (MW)
2018	6,31	169
2019	6,32	183
2020	6,15	196

The year 2020 is represented as the time when electricity demand in Kolaka, Sulawesi soared with the smelter procurement plan mentioned above.

4.1.2 Fuel Demand of BMPP

Power plant used to generate power for a need of project, in order to be compiled that no energy could not be created, thus the energy for electricity converse from turbine in power plant. Turbin takes fuel to consume and in this research were using natural gas fuel and light fuel oil.

4.1.2.1 Fuel Oil Demand

In this 60 MW BMPP study, the engine used was the Wartsila engine with the type 12V34 DF. In the engine guide project, it is known that fuel consumption is 191.4 g / kWh at full load (100%).

1. Calculation of fuel oil storage tank volume needed:
   WFO = Power x SFOC x Endurance
   Power = 60 MW
   SFOC = 191,4 gr/kWh
   Endurance = 10 days = 240 h

   WFO = 2756,16 Ton

2. Volume of Fuel Oil
   VFO = WFO / ρ FO
   ρ FO = 0,89

   VFO = 2756,16 / 0,89
   VFO = 3097 m^3

The storage tank needed for power plant would be on 2756,16 Ton a day and would install a storage fuel tank inside BMPP as much as 3097 m^3 capacity.

4.1.2.2 Natural Gas Fuel Demand

Natural gas is gaseous hydrocarbon consisting primarily of methane and ethane and commonly occurs in association with crude oil.

For calculation of BMPP demand on volume of gas and debit to be transferred in the system, natural gas demand should be counted as the initial data of BMPP had 60 MW. The energy of electricity in MW first need to be converted to Btu or british thermal unit, and have the energy needed 204,6 mmBtu.

By 2018 in Global Energy Statistical Yearbook 2019, Indonesia had become 9th of the highest producer of natural gas in the world. There are a few refineries of gas producer in Indonesia, some of them were at West Papua and Bontang.

in this research, the tank capacity of natural gas needs to be determined so that it can be considered as a supply of natural gas in an appropriate scenario. This of course requires a conversion standard to be used as a basis for calculation, the following is the conversion standard used:

1 MW is equivalent to 0.143 MMSCFD
1 MMSCFD is equivalent to 46 m3 of LNG
1 MMSCFD is equivalent to 1000 MMBTU

In calculation for the LNG supply in 60 MW then we would have 8,58 MMSCFD per days, and right on to the demand, scenarios of voyage from Bontang to Kolaka is about 2,4 days with speed of vessel 10 knot.

3. Round Trip

Round Trip Duration = Sea time + Port Time + Slack Time
Sea time = 2*Distance to Receiving Terminal/Ship Speed
= 4,8 Days
Port time = Assume 0,5 Days
Slack time= Assume 2 Days

Round Trip Duration = 4,8 + 0,5 + 2
= 7,3 Days

4. Demand

MMSCFD Demand = 60*0,143
= 8,58 MMSCFD

5. Volume LNG Storage Needed

Demand m^3 LNG = 8,58 * 46
= 2.882 m^3 LNG

4.1.3 Location of BMPP

Annihilating the research of Kolaka barge mounted power plant safety risk assessment, system to configuration to be first of method is arranged by sufficiently system and analysis of condition in the land of Kolaka, and BMPP specification. Kolaka had a few of land to be used and construction belongs to Indonesian Government as a potential land for this construction. Researcher assuming BMPP built to compete the sufficient accommodation of berth in Kolaka.

4.1.3.1 Pelabuhan Pelni Pomalaa

Pelabuhan Pelni Pomalaa described as a fishing port that managed by Kementrian Dinas Perhubungan Laut. Pelabuhan Perikanan Pomalaa Categorized as archipelago fishing port or so-called type b or ii (second) class port: Managed for a fishing vessel sized 15-16 GT. This port caters vessels from ZEE or archipelagic areal.

Figure 4. 2 Pelabuhan Pomalaa
(Source: Google Earth)

4.1.4 Comparing Chain of FSRU, FSU or Onshore terminal

To supply fuel in natural gas form to BMPP, configuration of supply chain system in this research had to be compiled. In order to compile the system, there was a few options of LNG supply could be remarked as a supply with FSRU or with FSU and a regasification unit onshore or a with an onshore storage tank and onshore terminal.

COSTS

Construction of the system would need to be considered by any capability of conditions that been held in which is take costs which described as Capital Expenditure and Operational Expenditures:

- Capital Expenditures means the intial cost taken for the construction including jetty with piping system, unloading lines, tanks, vessel, process plant, utilities and onshore interface
- Operational Expenditures consists of Fuel gas, personnel, maintenance, consumables, tugs and insurance.

Table 5. 0-3 CAPEX Onshore, FSRU, FSU
(Source: The Oxford Institute for Energy Studies, The outlook for floating storage and regasification units)

No	Component	Onshore (million dollar)	FSRU (New Build on million dollar)	FSU (New Build on million dollar)
1	Jetty Including Piping	80	80	80
2	Unloading lines	100	N/A	N/A
3	Tanks 1x180.000	180	in FSRU	in FSU
4	FSRU Vessel	N	250	150
5	Process Plant	100	in FSRU	100
6	Utilities	60	in FSRU	in FSU
7	Onshore Interface	N	30	30
CAPEX		520	360	360

Operational expenditures for those above are consisting of operational costs needed based on the record of *LNG Plant Cost Reduction 2014* from Oxford Institute for Energy Studies 2018 and in this research were taken 2.5% of capital expenditures.

Table 5. 0-4 CAPEX OPEX Unit
(Source: Source: The Oxford Institute for Energy Studies, The outlook for floating storage and regasification units)

Unit	CAPEX (m$)	OPEX (m$)
Floating Storage Unit	360	360
Floating Storage and Regasification Unit	360	360
Onshore Storage and Terminal	520	520

Project Schedule

Project scheduling of construction for FSRU, FSU and Onshore Facilities were concluded in the research of oxford institute with the capacity of 180.000 m^3 tank capacity and 3 mbtu gas transfer.

Table 5. 0-5 Project Schedule Build
(Source: Wartsilla Research on LNG Supply)

New Build Project	Schedule
Floating Storage Unit	25 months
Floating Storage and Regasification Unit	33 months
Onshore Storage and Terminal	60 months

Project to Cost Efficient Time

The efficient time of project was construct based on the function and vision of the project which compared to the costs it takes,

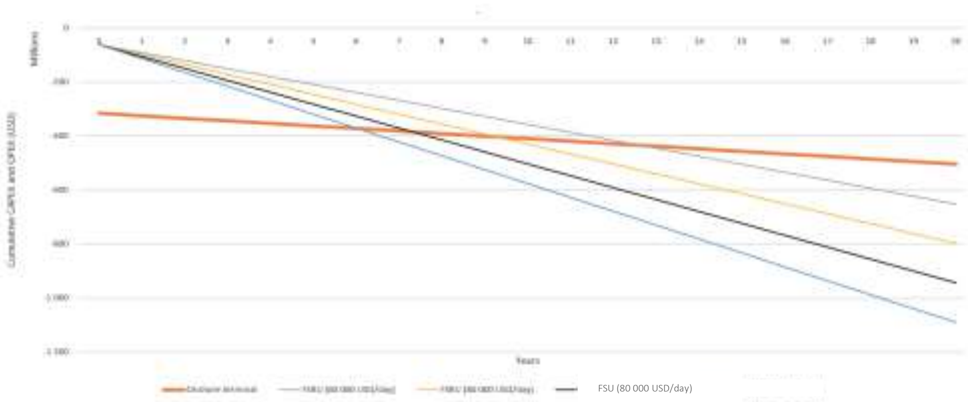


Figure 4. 3 Project to Cost Efficient Time

There were the conclusions of comparing graphic costs between three different facility. From figure, the start cost of onshore terminal is much risen then another facility compiling the construction cost of inland facility. Figure shows that there was an intersection point between FSRU with onshore terminal in defiance of charter cost of FSRU. These intersection concluding the cost of FSRU is more valuable and efficient if it only used for some times in a period of time.

Support Decision Making Using TOPSIS (Technique for Others Reference by Similarity to Ideal Solution)

Table 5. 0-6 Multiple Data to Decide

No.	Chain	CAPEX (m$)	OPEX (m$)	Project Schedule	Investment
1	FSU	360	9	17 months	< 6 years
2	FSRU	360	9	33 months	< 10 years
3	ONSHORE	560	14	60 months	> 13 years

From the data collected in Table 4.3, to decide from chain to supply gas in BMPP, researcher categorized the value in table to be counted as 1 – 5 scale from worst to the best and had Table 4.5.

Table 5. 0-7 Value for normalized calculation

No.	Chain	CAPEX (m$)	OPEX (m$)	Project Schedule	Investment
1	FSU	4	3	4	4
2	FSRU	4	4	2	3
3	Onshore Facilities	2	2	1	2
Pembagi		36	29	21	29
rij		6	5,38	4,58	4,58

To make a normalized matrix each criterion value is divided by the weight of the divider. Then each value of the matrix should be normalized with rij and have a Table 4.5.

Table 5. 0-8 Normalized Matrix

No.	Chain	CAPEX (m$)	OPEX (m$)	Project Schedule	Investment
1	FSU	6,67E-01	5,57E-01	8,73E-01	7,43E-01
2	FSRU	6,67E-01	7,43E-01	4,36E-01	5,57E-01
3	Onshore Facilities	3,33E-01	3,71E-01	2,18E-01	3,71E-01

As we had the normalized matrix, we should examine the defiation factors, max value is the highest value of each criterion in the normalized matrix weighted, while the value of min is the lowest value of each criterion in the weighted matrix. Max and min values can be seen in the Table 4.6

Table 5. 0-9 Maximum and Minimum Value

No.	Chain	CAPEX	OPEX	Project Schedule	Investment
1	FSU	6,67E-01	5,57E-01	8,73E-01	7,43E-01
2	FSRU	6,67E-01	7,43E-01	4,36E-01	5,57E-01
3	Onshore Facilities	3,33E-01	3,71E-01	2,18E-01	3,71E-01
Nilai Max		0,6667	6,67E-01	7,43E-01	8,73E-01
Nilai Min		0,3333	3,33E-01	3,71E-01	2,18E-01

Values of D + and D- are used to determine the results to be obtained by alternatives. The following calculations:

$D+_1 = \sqrt{}(0,667-0,667)^2+(0,557-0,742)^2+(0,873-0,873)^2+(0,742-0,742)^2$

$D+_1 = 0,185$

And;

$D-_1 = \sqrt{}(0,667-0,333)^2+(0,557-0,371)^2+(0,873-0,218)^2+(0,742-0,371)^2$

$D-_1 = 0,843$

From the calculation to determine D+ and D- we would have table 4.7

Table 5. 0-10 D+ and D-

D+	FSU	1,86E-01	D-	FSU	8,44E-01
	FSRU	4,74E-01		FSRU	5,75E-01
	Onshore	9,03E-01		Onshore	0,00E+00

The final result of value of each criterion following the results of each alternative and would be calculated with the following calculations:

FSU preference value: $\frac{0,843}{0,843-0,185}$
FSU preference value: 1,282

The Following preference value would be ranked after calculation above and the ranked preference value would describe in Table 4.8.

Table 5. 0-11 Ranked Value Preference

Ranked Value		
FSRU	V2	5,69E+00
FSU	V1	1,28E+00
Onshore	V3	0,00E+00

From the decision method using TOPSIS we could conclude the system supply of LNG would using FSRU.

4.1.5 Fuel Supply Scenario of BMPP

In working on risk assessment, the risks that can arise in this project have more than one possible time, therefore the writer makes a scenario to narrow the focus of the study. Through the limitation of research that only examines the risk assessment of the process of fuel transfer from fuel storage to the engine generator, the scenario created is the scenario when the fuel is being transferred both in the form of fuel oil and natural gas. The previous point states that the need for fuel can be met with conditions:

- LFO fuel has a storage tank with a minimum capacity of 3,097 m3
- LFO fuel has a 10-day endurance scenario with that capacity
- Natural gas fuel requires a storage tank with a capacity of 2,882 m3 of LNG
- The LNG distribution mechanism requires a minimum time of 7.3 days from LNG production to the planned BMPP port

Chronologically created scenario will be a process of transfer of fuel from fuel storage where natural gas starts from storage at the FSRU by going through a compression process to evaporation which makes the liquefied natural gas phase into gaseous natural gas and LFO with the assumption of LFO fuel storage tanks inside BMPP.

The author assumes the use of the type of fuel when operating BMPP uses only one type, when BMPP operates using LFO fuel, the use of natural gas will stop and while the use of LFO fuel is running, it is assumed to be the time for LNG Carrier to get LNG supply from Bontang which has reserves natural gas.

Meanwhile, when the use of fuel for BMPP is natural gas, that time BMPP will be used to fill fuel storage in BMPP. The length of time for filling will be used as an initial assumption in measuring BMPP fuel storage requirements so that the time used becomes more effective.

Table 5. 0-12 Scenario Fuel Supply

Scenario	**Gas Supply**	**LFO Supply**
Initial Use of BMPP	-	Loading station to tanks operability until day tank filled
Operational BMPP with LFO	LNG Carrier voyage to Bontang	Operational Tank to engine
Fuel Sharing Mode	Safety set to same high level as if operating in normal gas mode	As in operation, preparing MDO Fuel for switch to gas mode operation
Operational BMPP with Natural Gas from FSRU	Transfering natural gas	Off, filling BMPP LFO Storage Tanks

Project guide of Wartsila 34 DF stated that when fuel sharing mode is activated, the engine will utilize gas injection, main fuel injection and pilot injection. The benefits of this mode would be maximum fuel flexibility so operation of engines and utilization of boil-off gas would be optimized.

Then, this research would have an assessment of scenario 3 that had the setted conditions of safeties for gas mode.

CHAPTER V

HAZARD IDENTIFICATION

5.1 Determining the Potential Hazard

In term of fire causes, regarding phase from material of fire to turn conditions to fire is how was the changing of materials and combined with oxygen and heat turns the conditions to fire with the possible combinations turn them into several type of fire which was conducted into jet fire, flash fire, VCE or gas dispersion.

These several type of fire would also determine the safety or even the fatality a fire would costs. Jet fire, flash fire, VCE and gas dispersions has a differently parameter of causes such as pressure, flow, and temperature itself. In the case of making an analysis of the causes of accident events, researchers can collect data or conclude an assumption before further research using real events data at a previous time. one of them is to analyze the possibilities that make a fire with a certain temperature, pressure and flow that can be juxtaposed with the object of research being studied at this time. Determination of potential hazards is also limited by the possibility of the possibility of working principles that work in the system, not all principles of work on the system with conditions can cause BLEVE or VCE, because the category of occurrence of events from the analyzed hazard also has its own provisions. This research also limits the hazards that occur from the analysis in this chapter which will be the basis of work in the next chapter. But perhaps the most common event that occurs in fires where the system has desired pressure and temperature reaching the boiling point and ignition point in general will involve jet fire which is a flame at high pressure.

Pressure, temperature and flow are then analyzed in a group of nodes that allow for a fire to occur and are defined in hazards, but when the likelihood of a fire event can be taken, assuming that the real fire event in the previous time is most relevant when discussing the principle work of each component or instrument. Each instrument or component's performance is evaluated so as to get the possibilities that can cause a fire and define the type of fire. To represent and at the same time make consideration of the potential for a fire disaster, research is needed in principle from the work of each component or instrument calculated with the standard used. Quantitative calculation is used as one of the considerations and is carried out using Fault Tree Analysis with the output being a series of possible events from each condition to the simple working principle of each system that will bring up the most likely potential values of fire accident.

5.2 Ship to Ship Layout Scenario

BMPP operations that are illustrated by the layout are used as scenarios of accidents in several operating models. Limitations taken in making operating scenarios are the effects or impacts caused or changes in operations at times or conditions when there is a change in the crew's crossing. Scenarios on ship location will be assumed to be stationary, and are described in the following layout:

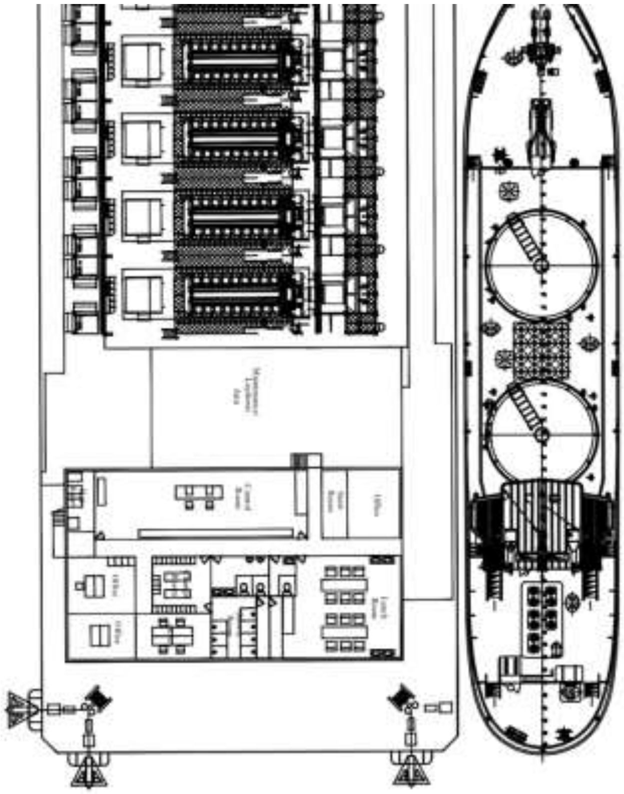


Figure 5. 1 Ship to Ship Layout Scenari

5.3 First P&ID Before Modified

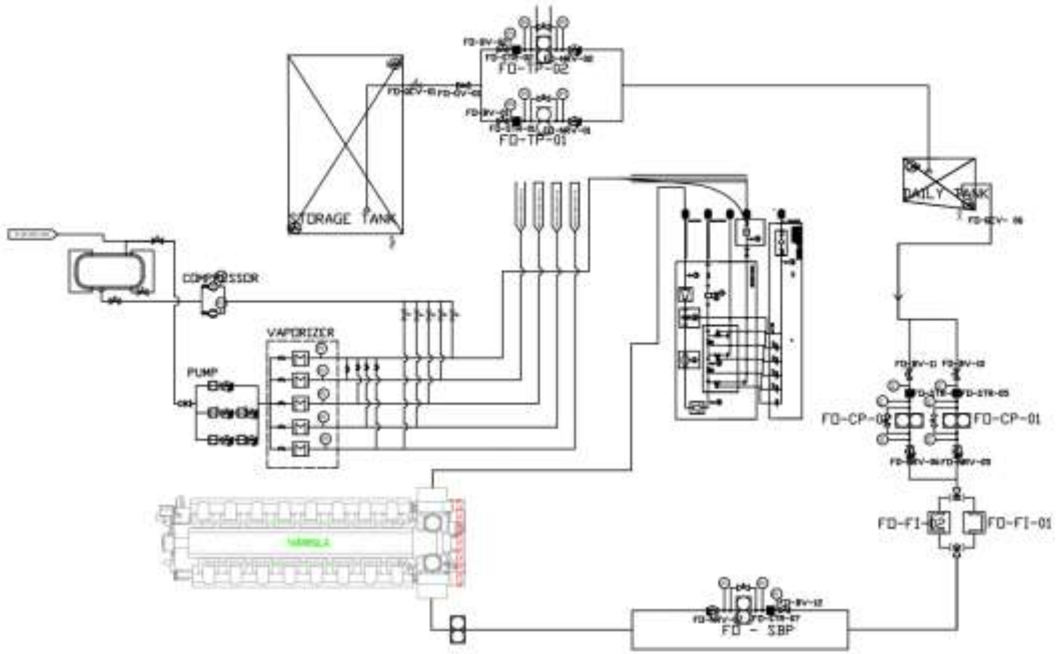


Figure 5. 2 P&ID Before Modified

5.4 System Configuration for Hazard Analysis

5.4.1 Sub-System Configuration

In determining the system to be made, the writer or researcher places the system broadly as a series of sub-systems that can be divided into sub-systems based on the type of fuel or working fluid that works on the sub-system. This case emphasizes the use of dual fuel systems which include Natural Gas and Fuel Oil. The purpose of using the dual fuel system is to be able to be an innovation in saving the use of fuel that is operated as a power plant in the South East Sulawesi region. Natural gas can have several scenario choices arranged as a supply of natural gas to BMPP and has been explained and analyzed by the author in order to determine the supply of Natural gas is to use the FSRU. While the supply of fuel oil is simplified to be the supply of fuel oil storage installed in BMPP.

Table 5. 0-1 Table of Sub-system Configuration

Sub System	Pure Chemical	Supplied By	Process Flow
Natural Gas	Methane	FSRU	1. FSRU Storage
			2. Regasification Unit FSRU
			3. Flexible Hose
			4. GVU
Fuel Oil	N-Octane	BMPP Storage Tank	1. BMPP Storage Tank
			2. Transfer Pump Unit
			3. Fuel Daytank
			4. Daily Pump Unit

5.4.2 Natural Gas Group Configuration

Determination of groups based on each sub-system is done to simplify the sub-system in order to get a group that is more easily analyzed so that the assessment and analysis of the fuel transfer system to BMPP is more accurate when viewed in terms of analysis which will be done well with further quantitative analysis , as well as a qualitative analysis that will be illustrated with the consequences of the analysis, namely fire modeling. Simplification of the subsystem can be divided by considering operating pressure, operating temperature. In the sub-system the transfer of natural gas from the FSRU to BMPP to some pressure and temperature differences is illustrated in the table.

Table 5. 0-2 Natural Gas Group

Group (Source)	Working Temperature (Celsius)	Working Pressure	Phase
FSRU Storage Tank	-165	3	Fluid
FSRU Heat Exchanger	0	5	Gas
Compressor	-40	6	Gas

In the table, it can be seen the difference in the process temperature in the process of releasing LNG in liquid form into the heat exchanger into one group that is distinguished both in differences in temperature, pressure and phase. Meanwhile, when viewed in groups from the heat exchanger to the GVU included in the third group, lies in the difference in temperature and pressure even though the working fluid phase is gas. Assumptions in the analysis made in this study, LNG storage for BMPP fuel is not placed at BMPP. Therefore, the LNG storage area as well as the regasification unit in this system is located in the FSRU which will be transferred using the ship-to-ship transfer mode. LNG storage tanks, as in the naming, are useful for storing natural gas fuels for BMPP that are determined on a scale according to the needs of use and FSRU time to refill all storage tanks taken with LNG carriers from LNG production in Kalimantan. LNG from the FSRU storage tank will be loaded on the BMPP in the form of gas according to the engine guide project that will be used by the BMPP. To convert the LNG phase into a gas phase, a regasification tool is needed which in this study used a heat exchanger which became the second group of analysis this time. In the natural gas that is phase changed using a heat exchanger then transferred to the engine on the BMPP through a flexible hose for transfer between vessels in extreme temperatures and through the gas valve unit which is a safety instrument as well as a temperature and pressure regulator as well as prevention to the general system before entering into engine.

This group will then be simplified again and become part of the node as a material to be analyzed both in quantitative analysis and qualitative analysis. Each group will be described as an instrument whose instrument work is involved as the smallest part of the work of the system segmentation.

5.4.3 Fuel Oil Group Configuration

Grouping is useful for simplifying analysis for research in addition to groups from natural gas supply as well as groups from the fuel oil sub-system. This sub-system is also divided into several groups by considering the differences in pressure, as well as the temperature acting on the system.

The division of groups in the fuel oil sub-system is divided by consideration of differences in temperature and pressure differences used in each source group based on the project guide on the engine in the use of both the fuel tank settling and daily tank.

Storage tanks referred to in the division of source groups are settling tanks that are used as storage tanks before fuel is transferred into the tank to be treated to be ready for use by engines from BMPP. The settling tank used is built simultaneously with BMPP and maintains a temperature of 40C with a pressure of 3 bar in the settling tank.

Day Tank at BMPP is useful for carrying out the preparation phase of fuel oil that has passed through several separator units after moving from the settling tank which is then adjusted to the temperature and pressure of the fuel oil.

Daytank heats fuel oil to sufficient temperature and sufficient pressure to be used in accordance with the provisions of the engine project guide.

Table 5. 0-3 Fuel Oil Group

Group Source	Working Temperature (Celsius)	Working Pressure (Bar)	Phase
BMPP Storage Tank	40	3	Fluid
BMPP Day Tank	90	5,5	Gas

5.1.1 Instrument of Each Group

In determining the group by considering the differences of several things up to become five groups of the total system, now researchers need to consider the instruments available from each group so that when it comes to the analysis phase, researchers can easily analyze several categories of potential hazards.

In the table above, the main instruments that can be involved in the natural gas transfer process in the first group are shown. The LNG tank stores LNG reserves with a temperature of -165 Celsius with a liquid fluid phase which has a tank pressure of three bar. LNG is pumped at cryogenic temperatures with a pressure of four bars with a pump. In the transfer process between the LNG tank and the heat exchanger, the pump passes through a quick closing valve as a safety valve for the system that can prevent flow when the time is undesirable, LNG through a non-return valve in order to prevent the fluid leading to the LNG tank that can provide back pressure and lead to more potential for accidents.

In the second group, LNG is converted into a gas phase which has a boiling point of approximately -161 Celsius to a gas phase at minus 40 degrees Celsius which is then transferred along with the inert gas from the compressor. After the LNG phase of the heat exchanger has changed then natural gas is transferred through a flexible hose that has resistance to cryogenic temperatures. Before entering into the flexible hose, natural gas through several stages of safety valves, both manual and automatic with a gate valve or check valve.

Before the gas is supplied to the engine it passes through a Gas Valve Unit (GVU). The GVU include a gas pressure control valve and a series of block and bleed valves to ensure reliable and safe operation on gas. The unit includes a manual shut-off valve, inerting connection, filter, fuel gas pressure control valve, shut-off valves, ventilating valves, pressure transmitters/gauges, a gas temperature transmitter and control cabinets. The filter is a full flow unit preventing impurities from entering the engine fuel gas system. The pressure drop over the filter is monitored and an alarm is activated when pressure drop is above permitted value due to dirty filter. The fuel gas pressure control valve adjusts the gas feed pressure to the engine according to engine load. The pressure control valve is controlled by the engine control system. The system is designed to get the correct fuel gas pressure to the engine common rail pipe at all times. Distribution and instruments in the natural gas supply sub-system at BMPP in this study were analyzed from group one to group 3, while the supply of fuel oil was observed from group 4 to group 5.

To ensure sufficient time for settling (water and sediment separation), the capacity of each tank should be sufficient for min. 24 hours operation at maximum fuel consumption. The tanks should be provided with internal baffles to achieve efficient settling and have a sloped bottom for proper draining. In the tank mode the temperature of the fuel oil is maintained at 40 degrees Celsius so that the separation of sedimentation and water can occur. Then the fuel oil is transferred to the fuel oil transfer pump which has several safety units and fuel oil purification, which is a filter and is secured with a non-return valve to prevent back pressure on the system.

At the transfer pump then the fuel oil is transferred into the fuel oil daytank. Fuel oil day tanks shall be provided with heating coils and insulation. It is recommended that the viscosity is kept below 140 cSt in the day tanks. Due to risk of wax formation, fuels with a viscosity lower than 50 cSt at 50°C must be kept at a temperature higher than the viscosity would require. Continuous separation is nowadays common practice, which means that the HFO day tank temperature normally remains above 90°C. After going through the daytank that prepares the fuel oil then it is transferred with a feedpump into the engine by passing a refining filter which is useful to ensure the need for fuel oil that enters the engine. The pressure considered to be acceptable by the engine when entering the engine is 5 bars or the equivalent of around 720 psia.

Table 5. 0-4 Table of Instrument System

Instrument	Unit				
	Group 1	Group 2	Group 3	Group 4	Group 5
LNG Pump	5	-	-	-	-
LNG Storage Tank	1	-	-	-	-
Check Valve	5	4	-	2	2
Quick Closing Valve	1	-	-	-	-
Ball Valve	1	-	-	4	2
Gate Valve	-	8	3	-	-
Heat Exchanger	-	4	-	-	-
Filter	-	-	2	1	2
Solenoid Valve	-	-	6	-	-
Vent Valve	-	-	2	-	-
Compressor	-	-	1	-	-
Block Valve	-	-	4	-	-
Settling Tank	-	-	-	1	-
Transfer Pump	-	-	-	2	-
Injection Pump	-	-	-	-	2
Daytank	-	-	-	-	1

5.5 Hazard and Operability Study

A HAZOP study is a detailed process carried out by a dedicated team to identify risks and operability problems. HAZOP studies deal with the identification of potential deviations from the design intent, examination of their possible causes and assessment of their consequences (IEC, 2016). This research would be using standard of British HAZOP BS IEC 61182: 2016. The initial things need to take is to define the system into a few nodes, nodes that defined are to be analyzed the potential danger and consequences of the failure. HAZOP would compile in the form of documents or reports. HAZOP defines in the documents as guideword, deviation, possible causes, consequences, safeguard, comment and action needed.

1. Guide Word

Guide word guide words for keywords to guide the thoughts of the researcher or who play a role in the analysis of the objectives to focus the study and obtain ideas through discussion to benefit from the completeness of the study. Key words agreed in the words guide are determined by examples in the table as written in BS IEC 61182: 2016 and represented in the following table.

Table 5. 0-5 Table of Guide Word Definition

Guide Word	Meaning
NO OR NOT	Complete negation of the design intent
MORE	Quantitative increase
LESS	Quantitative decrease
AS WELL AS	Quantitative modification/increase
PART OF	Quantitative modification/decrease
REVERSE	Logical opposite of the design intent
OTHER THAN	Complete substitution

2. Deviation

Deviation Is the result of speculation based on guidewords and working principles and the role of the process functions being analyzed. Deviations that appear are taken from HAZOP BS IEC 61882: 2016 referring to differences in flow, temperature, pressure and level. Deviation will later be used as the thinking base of the analyzer in order to determine the possibilities of the system that can cause failure in the form of work accidents. In this case the limits of the incident are things that can cause a fire accident.

Table 5. 0-6 Table of Guide Word Description

Guide Word	Flow	Temperature	Pressure	Level
NO OR NOT	No Flow	-	-	No Level
MORE	High Flow	High Temperature	High Pressure	High Level
LESS	Less Flow	Low Temperature	Low Pressure	Low Level
AS WELL AS	Contaminated	-	-	-
PART OF	Concertation	-	-	-
REVERSE	Back Flow	-	-	-
OTHER THAN	Wrong Instrument	-	-	-

3. Possible Causes

Possible causes are things that allow the deviation that has been written above. Possible causes of an event can be analyzed from the process of deviations that occur at the node that has been determined by observing the working principle and function of instrument in a node.

4. Consequences

The consequences are the result of a hazardous event. The consequences can be analyzed by looking at the impact of a process after knowing the deviations on the components of an equipment. The consequences that may occur occur various kinds of things, but in this study the consequences that arise are limited as things that can trigger fires.

5. Safeguard

Is a term for a component or instrument that can prevent deviations from occurring in a process with an example giving a warning indication with a reminder alarm.

6. Comment

Comments are responses that state the degree to which a consequence is acceptable or unacceptable.

7. Actions

Action, if a cause of an event could be described to have a negative consequence, we should look up to any behavior to be done as counted in action. Action should be separated into two purpose, to reduce cause of an event or to clear up the consequences. Oftenly, action would be prioritized to reduce the cause of an event that could decreaase the consequence automatically.

8. Node

In determining the nodes in the analyzed system, researchers consider the category or grouping of the most efficient systems to be analyzed. These considerations are obtained from the results of the system configuration that has been analyzed by previous authors in the division of groups. But in this case, there are several possibilities in the third group that have the source of the compressor in the natural gas supply system after passing through the heat exchanger. The author assumes that the compressor on the system is installed on BMPP and operates when supplying natural gas. So, get the provisions of the node to be analyzed as follows:

- Node 1 – FSRU Tanks to Vaporizer
  Node 1 describes the transfer process from the LNG tank in the FSRU until it is verified through a vaporizer at the FSRU. In the transfer system from the LNG tank will pass through pipelines that are pumped at extreme temperature conditions using pumps and treated in regasification units with temperature regulation so that they become gas phase in the appropriate temperature. This node also includes equipment such as globe valves, temperature transmitters, temperature indicators, pressure transmitters, pressure indicators and flow elements.
- Node 2 – Flexible Hose
  Node 2 describes the natural gas process when the gas phase passes through the flexible hose by compressing it into the compressor to BMPP. This process includes the transfer process from the LNG phase which has passed through the vaporizer into gas which is then transferred to BMPP using a compressor. At this node there are several supporting components including the temperature transmitter, temperature gauge, pressure gauge and pressure transmitter.
- Node 3 – Gas Valve Unit
  Node 3 describes the process of the gas valve unit which is useful to ensure the reliability and safety of gas operations by preventing impurities from the gas entering the engine. GVU consists of shut-off valves, inerting connections, filters, fuel gas pressure control valves, shut-off valves, ventilating valves, pressure transmitters and gauges, a gas temperature transmitter. The system is designed to get the correct fuel gas pressure to the engine common rail pipe at all times.
- Node 4 – LFO Storage Tank to LFO Day Tank
  Node 4 is the process of transferring LFO from storage tanks as a total storage area from BMPP to LFO Day tanks or tanks that are used to adjust engine needs more optimally in adjusting LFO conditions. The main component in the transfer process to Daytank is a supply pump that has a temperature gauge and pressure gauge as well as taking into account the condition of the tank.
- Node 5 – LFO Day Tank to Engine
  From Day tank, fuel oil pumped using feed pump, after through flow meter and then before went to injection pump, the fuel oil must be heated in final heater, after that the fuel oil measured the viscosity using viscosity meter and the final entry injection pump with minimum pressure of specification.

9. P&ID Modifying
   Dalam menyusun system analisis pada transfer bahan bakar BMPP. Peneliti menemukan penemuan ketika mengamati beberapa hal yang ada pada P&ID dengan mendahulukan penelitian HAZID ke dalam aturan kelas ABS maupun SOLAS. Sehingga P&ID pada sistem yang akan dianalisis ditambahkan dengan beberapa pengamanan sesuai dengan ketentuan yang ada. Penyempurnaan P&ID ini ditambahkan beberapa shutdown valve serta pressure indicator yang dapat mencegah terjadinya kecelakaan sesuai aturan ABS.

5.6 System P&ID

Figure below showing configuration of system that had already modified. As described to be colorized category in nodes were Node 1 (Red line), Node 2 (Green line), Node 3 (Blue Line), Node 4 (Magenta Line) and Node 5 (Yellow Line).

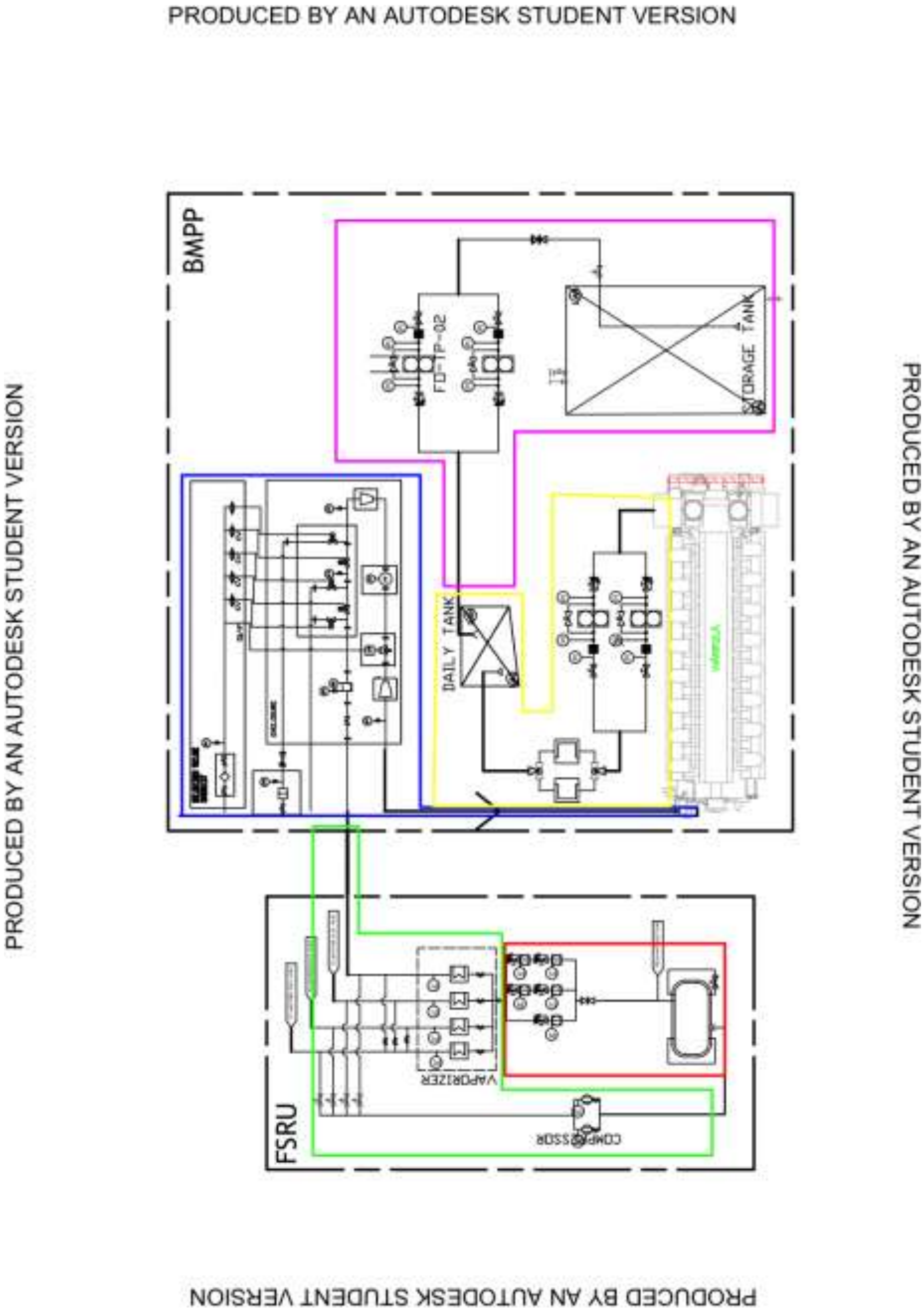


Figure 5. 4 Modified P&ID

5.7 HAZOP Sheet

Table 5. 0-7 Table of HAZOP Sheet Node 2

Study Title		NODE 2					
Drawing							
Part Considered							
Design Intent		Fluid : LNG			Destination :Flexible Hose		Sheet 1 of 1
		Source : Vaporizer FSRU			Temperature : 17 C		Pressure : 50 bar
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required
1	No	No Flow	Connection between manifold and flexible hose is disconnected	No NG Supply	None	Situation is not acceptable	add ESD before flexible hose
2		No Pressure	Leakage on pipeline during transferring process	No NG Supply and leakage lead to fire	None	Situation is not acceptable	Routine check on pipe and connection before starting operation
3	No	Less Flow	Leakage of pipeline on manifold 1 connection with flexible hose	No NG Supply	None	Situation is not acceptable	Routine check on pipe and connection, install flowmeter
4				Lead to fire			
5	No	Less Pressure	Leak on flexible hose	Transferring takes time more than actual time	None	Situation is not acceptable	Routine check on pipe and connection before starting operation

In the HAZOP Sheet on node 2, the analysis is used with the guide words No and Less by identifying the process of supplying natural gas from the heat exchanger to the flexible hose. Some possible events that can lead to undesired events with several possible causes include the interrupted connection between the manifold and the flexible hose that can close the automatic shutdown valve on the pipe line leading to the flexible hose will make the flow in the pipe until there is no flow. In the transfer pipe leakage that makes the flow of gas to the flexible hose does not exist. Leakage of pipes in the manifold between the inert gas from BOG and the transfer from the heat exchanger can cause a lack of flow which leads to gas release and fire in the manifold. Leakage on the flexible hose is also possible and makes the gas wasted in the pipe which causes the possibility of fire.

5.8 HAZOP Result

After identifying hazards using the HAZOP method, identification of consequences scenarios that can occur on the Ship to Ship LNG Transfer and Engine fuel system can be displayed in the Compatibility Matrix table as below.

Table 5. 0-8 Result of Hazard Identification

Node	Consequence					
	Jet Fire	Flash Fire	Gas Dispersion	VCE	BLEVE	Pool Fire
1	YES	YES	YES	YES	NO	NO
2	YES	YES	YES	NO	NO	NO
3	YES	YES	YES	NO	NO	NO
4	NO	NO	NO	NO	YES	YES
5	NO	NO	NO	NO	YES	YES

Possible events that can cause VCE are when there are receivers or instruments that are tangible as closed containment systems. VCE can occur if there is a change in pressure on a closed tangka with an ignited source from the exit hole of methane while there is another hole into the air or O2, a mixture of these two gas fluids which can realize the presence of VCE in the levels of 15% methane and 5 % air.

"Halaman ini sengaja dikosongkan"

CHAPTER VI

FREQUENCY ANALYSIS

6.1 Overview

One method that must be done in risk assessment is to do frequency analysis. Frequency analysis is performed to determine the probability of failure of a component in a system that can initiate a system failure. If a system failure occurs, it can initiate a hazard event. The standard used in frequency analysis is Det Norske Veritas (DNV) Failure Frequencies Guidelines for Process Equipment Leak Frequency Data for Use in Quantity Risk Assessment (QRA). Frequency analysis methods used are fault tree analysis (FTA) and event tree analysis (ETA). This method uses a bottom-up approach where the analysis starts with the chance of failure of a component that initiates a system failure and continues with the occurrence of a hazard. Frequency analysis in this final project aims to calculate the frequency of failures of a system. In the FTA method the final result is the gas release frequency from each node and for the ETA method the final result is the frequency of the hazard caused by the system at each node. To do frequency analysis, it needs failure data from a system. Therefore, it is necessary to calculate the failure data of a system in the form of leakage and system failure.

6.2 Result of Leakage and Failure Number

Node 4

HAZOP or Hazard and Operability is one way to identify potential hazards contained in a system. HAZOP includes examining the system, the processes that occur at a facility and evaluating the deviations that occur on that system. Deviation is a deviation that can occur in a system. Deviations are based on keywords (high, low, more and less) pre-arranged by BS IEC 61882-HAZOP Guideline. The HAZOP process includes a process of determining nodes, devisions, safeguards and other supporting criteria.

In describing the risks that exist in node one and describe it in the FTA modeling, according to the function in node 4, namely to transfer LFO from the storage tank as the initial storage area measured according to the capacity and length of time of use of a vessel until it is transferred into the Daytank which is the storage place to conduct treatment or preparation so that when the LFO enters the machine in conditions suitable for the desired conditions of the machine.

In describing the risks that become the top event of a series of fire events, limitation of events is taken that is the event where the LFO exits the system unexpectedly. Events that can realize the occurrence of LFO Release conditions are determined from the possibility of working principles in the system that is not appropriate. The analysis has been used with Hazard and Operability Study (HAZOP) in accordance with the working principles of the existing instruments.

The description of events concluded in the working principle and the group division to be used as the event of each Fault Tree construction is divided into the possibility of leakage in the system and the failure of the instruments, then each group is mapped to the possibility of instruments that can cause leakage or malfunction among them are pipe leaks, pump leaks, valve leaks and leaks from safeguards; instruments that can cause fire accidents in terms of instrument failure are also divided into pipe failures, failure pumps, failure valves and failure safeguards.The difference between the distance of two of the pipe diameters is then made into a frequency format that will be included in the value in the Fault Tree Analysis. The value used in the Fault Tree is the accumulative value of the additional instruments along with the valve arranged at a distance of the difference in value from each possible hole event. All valve calculation tables, and other instruments are represented in the following table:

The fuel specifications are based on the ISO 8217:2012 (E) standard. Observe that a few additional properties not included in the standard are listed in the tables. The required gas feed is depending on the lHV. In certain situations, during normal operation of a DF-engine, as well as due to possible faults, there is a need to safely ventilate the fuel gas piping. During a stop sequence of a DF-engine gas operation the GVU and DF-engine gas venting valves performs a ventilation sequence to relieve pressure from gas piping. Additionally, in emergency stop V02 will relief pressure from gas piping upstream from the GVU. Heavy fuel (residual, and mixtures of residuals and distillates) must be cleaned in an efficient centrifugal separator before it is transferred to the day tank. Classification rules require the separator arrangement to be redundant, so that required capacity is maintained with any one unit out of operation. All recommendations from the separator manufacturer must be closely followed.
Centrifugal disc stack separators are recommended also for installations operating on MDF only, to remove water and possible contaminants. The capacity of MDF separators should be sufficient to ensure the fuel supply at maximum fuel consumption. Would a centrifugal separator be considered too expensive for a MDF installation, then it can be accepted to use coalescing type filters instead, A coalescing filter is usually installed on the suction side of the circulation pump in the fuel feed system. The filter must have a low pressure drop to avoid pump cavitation

Table 6. 1 Equipment and Safeguard of Leak Frequency Process Transfer LFO

Node 4 Process Transfer LFO Daily Tank								
No.	Equipment	Code	Size	Leak Frequecny/Hole Diameter				
				1 – 3 mm	3 – 10 mm	10 – 50 mm	50 – 150 mm	> 150 mm
1	Flange	-	150 mm	6,09E-05	2,56E-05	1,08E-05	2,28E-06	3,23E-07
2	Ball Valve	-	150 mm	6,99E-05	3,21E-05	1,52E-05	3,58E-06	5,38E-07
3	Quick Closing Valve	-	150 mm	8,19E-05	3,52E-04	1,53E-04	3,31E-05	4,76E-06
4	Actuated Valve	-	150 mm	8,19E-05	3,52E-04	1,53E-04	3,31E-05	4,76E-06
5	Non Return Valve	-	125 mm	6,06E-05	2,79E-05	1,31E-05	3,10E-06	4,67E-07
6	Filter	-	-	1,90E-03	9,82E-04	5,30E-04	1,44E-04	2,34E-05
7	Actuated Valve	-	150 mm	8,19E-05	3,52E-04	1,53E-04	3,31E-05	4,76E-06
8	Ball Valve	-	150 mm	6,99E-05	3,21E-05	1,52E-05	3,58E-06	5,38E-07
9	Filter	-	-	1,90E-03	9,82E-04	5,30E-04	1,44E-04	2,34E-05
10	Non Return Valve	-	125 mm	6,06E-05	2,79E-05	1,31E-05	3,10E-06	4,67E-07
11	Actuated Valve	-	150 mm	8,19E-05	3,52E-04	1,53E-04	3,31E-05	4,76E-06
TOTAL				**7,39E-03**	**3,52E-03**	**1,74E-03**	**4,37E-04**	**6,83E-05**

Node 4 Process Transfer LFO Daytank								
No.	Equipment	Code	Size	Leak Frequecny/Hole Diameter				
				1 - 3 mm	3 - 10 mm	10 - 50 mm	50 - 150 mm	> 150 mm
1	Pressure Indicator	-	19,05 mm	3,57E-04	1,57E-04	7,00E-05	1,56E-05	2,28E-06
2	Pressure Indicator	-	19,05 mm	3,57E-04	1,57E-04	7,00E-05	1,56E-05	2,28E-06
3	Pressure Indicator	-	19,05 mm	3,57E-04	1,57E-04	7,00E-05	1,56E-05	2,28E-06
4	Pressure Indicator	-	19,05 mm	3,57E-04	1,57E-04	7,00E-05	1,56E-05	2,28E-06
5	Pressure Indicator	-	19,05 mm	3,57E-04	1,57E-04	7,00E-05	1,56E-05	2,28E-06
6	Pressure Indicator	-	19,05 mm	3,57E-04	1,57E-04	7,00E-05	1,56E-05	2,28E-06
TOTAL				**1,42E-03**	**6,28E-04**	**2,80E-04**	**6,24E-05**	**9,12E-06**

The data is taken from the number of instruments in the layout drawing used as the basis for analyzing this study, the pressure indicators are placed in special places where monitoring of the pressure in the system is crucial.

The values obtained in the table are the same because the factors used for the calculation are the same, where if the size of the connection in the pressure indicator with the pipe system is between 10-100 mm, so the calculation with the pipe inlet size is considered not to affect the likelihood of a fire accident.

In the LFO fuel transfer system from the storage tank, of course, using a pipe which is used as a medium for the removal of the fuel itself, the pipe has the potential to cause a fire accident, namely the leakage of the pipe. This potential needs to be calculated so that it can be prevented and overcome if indications of a fire accident occur. Calculation of the possibility of leakage in the pipeline is also regulated in Det Norske Veritas (DNV) Failure Frequencies Guidelines for Process Equipment Leak Frequency Data for Use in Quantity Risk Assessment (QRA).

From the existing data table from the OREDA (Offshore Reliability Data Handbook - DNV), the authors conclude by representing the data into the HAZOP that the authors have made, the results of these considerations form one of the frequency tables for the failure events of the valve as follows:

In the formulation of the Fault Tree, the possibility of failure is also formulated from the pump and also the existing safeguard, from the data in OREDA, the probability of failure frequency from the pump and safeguard is obtained as follows:

So that from all components and frequency of failures that have been identified in the calculation and calculation for determination, the following FTA form is obtained:

Writing the frequency value per year listed in the research table is obtained from the Guidelines for Chemical Process Quantitative Risk Analysis, from the research data. Research Guidelines for Chemical Process Quantitative Risk Analysis collects research data that has been observed in a long enough period of time to be able to deduce the values of the frequency of failure on the instrument. Failures that were recorded in the source study collected workplace accidents at a massive number of sources. But in this study, researchers put forward the possibility of events that occur based on the results of hazard analysis on the HAZOP Sheet that has been observed before and found the following results.

Table 6. 2 Failure Mode of Valve in Daytank LFO Transfer

No.	Equipment	Code	Failure Mode	Failure/year	/10^6 hours
1	Ball Valve	-	Fail to close on demand	6,5411E-10	5,73
2	Ball Valve	-	Fail to open on demand	3,7785E-10	3,31
3	Ball Valve	-	Ext. Leak	2,169E-11	0,19
4	Ball Valve	-	Fail to close on demand	6,5411E-10	5,73
5	Ball Valve	-	Fail to open on demand	3,7785E-10	3,31
6	Ball Valve	-	Ext. Leak	2,169E-11	0,19
7	Quick Closing Valve	-	Fail to close on demand	1,8174E-09	15,92
8	Non Return Valve	-	All modes	3,8813E-11	0,34
9	Non Return Valve	-	All modes	3,8813E-11	0,34
10	Non Return Valve	-	All modes	3,8813E-11	0,34
11	Non Return Valve	-	All modes	3,8813E-11	0,34
12	Ball Valve	-	Fail to close on demand	6,5411E-10	5,73
13	Ball Valve	-	Spr. Operat.	8,9041E-11	0,78
14	Globe Valve	-	Fail to close on demand	2,8653E-10	2,51
15	Globe Valve	-	Abn. Ins. Read	1,4498E-10	1,27
TOTAL				5,25457E-09	

Table 6. 3 Pump Failure Mode Number of Failure

Node 4 (Transfer Pump Failure Frequency)					
No.	**Equipment**	**Code**	**Failure Mode**	**Failure/year**	**/10^6 hours**
1	Trf Pump	-	Fail to start on demand	2,88E-10	2,52
2	Trf Pump	-	Fail to stop on demand	1,1416E-11	0,1
3	Trf Pump	-	Breakdown	1,4498E-10	1,27
TOTAL				4,44E-10	

Table 6. 4 Safeguard Failure Frequency Number

Node 4 (Safeguards Failure Frequency)				
No.	**Equipment**	**Code**	**Failure Mode**	**Failure/year**
1	Pressure Indicator	-	Fail to operate	2,10E-10
2	Pressure Indicator	-	Fail to operate	2,10E-10
3	Pressure Indicator	-	Fail to operate	2,10E-10
4	Pressure Indicator	-	Fail to operate	2,10E-10
5	Pressure Indicator	-	Fail to operate	2,10E-10
6	Pressure Indicator	-	Fail to operate	2,10E-10
TOTAL				**1,26E-09**

In the description that has been submitted previously by taking the source of the Guidelines for Chemical Process Quantitative Risk analysis, the intended value is each individual value that can be seen in the table in the definition of failure mode with the failure value submitted in the following column. Researchers categorize several instruments with different functions of the instruments themselves. In table 6.2 the depiction of the frequency of the valve failure, which functions as a flow opening or closing flow under the desired conditions. Table 6.2 is a description of the frequency of safeguard failures that have the potential to fail to detect changes or things that do not fit the desired conditions. Table 6.3 illustrates the failure frequency at the pump which is an instrument with the purpose of providing power to the liquid fluid in the system to move in the desired direction.

6.3 Result of Fault Tree

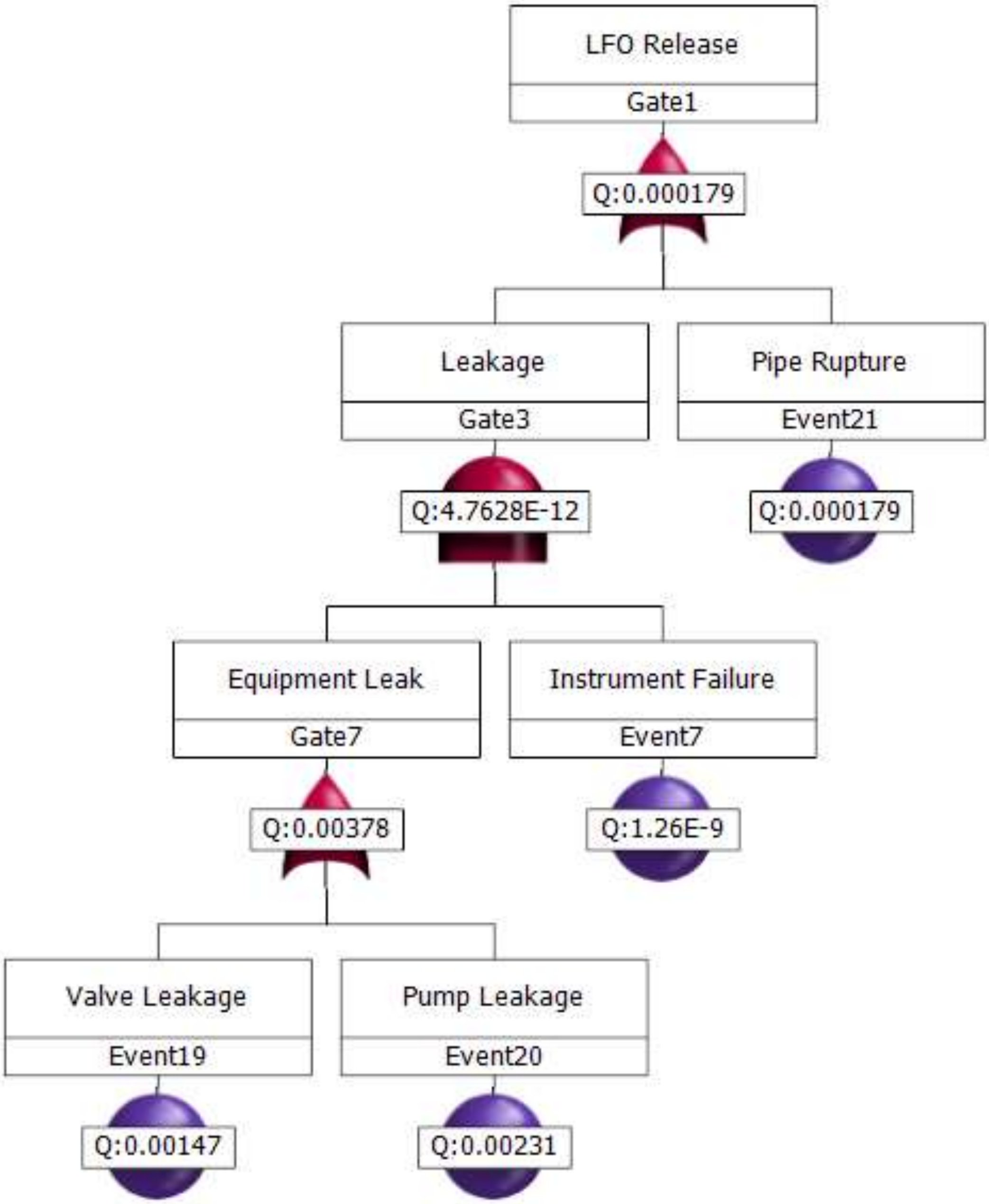


Figure 6. 1 Fault Tree Node 4

FTA is function oriented or better known as the "top down approach" because this analysis starts at the system level (top) and continues downward (Priyanta, 2000). Fault Tree Analysis functions as a method in calculating the frequency of failures with the top event being the leak of gas from the pipeline in the STS LNG transfer system. Frequency calculation in this study uses Relex 2009 software. Relex 2009 is software that can simplify calculations with the help of logical gates. In general, FTA calculations use 2 types of logical gates, namely "AND" and "OR". This logical gate will connect the top event to the basic event so that the failure frequency value can be obtained. FTA analysis is very closely related to the use of "and" or "or" logic gates. The following is an explanation of this

6.4 Result of Frequency Analysis with FTA

Each stain and system distribution that has been analyzed for the possibility of hazard is then analyzed and calculated based on the provisions in determining the frequency of possible failures in the FTA and made with a Fault Tree so that the work system of the BMPP Fuel Supply can be described and the likelihood of events that can cause an event fire accident. After all the considerations and calculations have been calculated it will be found to be a recapitulation of data from each calculation so that it can be continued into the next analysis. The results of recapitulation of FTA data are illustrated in the following table.

Table 6. 5 Result of Frequency Analysis in FTA

Node	Bore Scenario				
	1-3 mm	**3-10 mm**	**10-50 mm**	**50-150 mm**	**>150mm**
1	4,42E-03	1,72E-03	8,34E-04	N/A	N/A
2	5,90E-03	2,78E-03	5,90E-03	N/A	N/A
3	1,19E-02	5,59E-03	2,71E-03	N/A	N/A
4	8,03E-04	3,69E-04	1,79E-04	4,34E-05	N/A
5	1,06E-03	4,99E-04	2,42E-04	5,88E-05	N/A

On the results of Frequency Analysis with the Fault Tree Analysis method. described some of the results of the events that occur from each node in the description in the previous chapter by identifying the instrument and the value of failure in frequency per year taken from the CCPS. This calculation is also taken from the conclusions that are available so that when viewed in the table there is a column that mentions N / A because it is not possible for the occurrence of holes formed in the scenario in the research system this time due to inadequate pipe size.

6.5 Result of Event Tree Analysis

To identify the graphical logic model which identifies and quantifies possible outcomes following an initiating event, event three analysis system can be sufficient for an application of technological and systematical problems as in this research case the fuel supply system of Barge mounted power plant. Preincident event trees can be used to evaluate the effectiveness of a multielement protective system.

In this research as a complementary methods, the event tree built shall be an postincident event tree that can be appended to those branch. Result outcomes in the postincident event tree shall be the failure of the system and in this research, the end of the top branch or final event is Fuel Release whether it is Fuel or Gas. For example, in this research shown the event tree analysis of research on Node 1 as shown below:

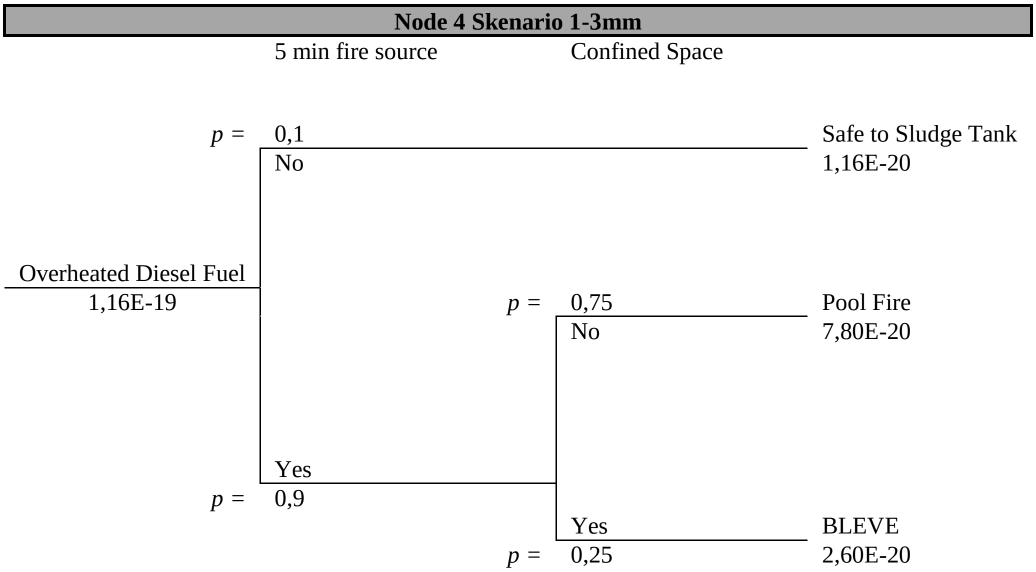


Figure 6. 2 ETA Node 4

6.6 Result of Jet Fire Frequency

Jet fire will be caused by leakage in the gas accompanied by the ignition of the flame directly. The possibility of jet fire is when the gas is in the liquid and low-pressure phase. Fire T fire type can generally occur in gas transfer process that has become liquid phase. Generally, jet fire has a heat transfer rate above 200 kW/m2. The damage caused by jet fire has a serious level of damage.

The damage caused by jet fire has a serious level of damage. In term to define the frequency in each of event that caused as fire accident so the calculation of process each bore then counted and had the result as shown below:

Table 6. 6 Result of Jet Fire Frequency per-Bore Diameter

Node	Frequency of Jet Fire per-Bore Diameter		
	1-3mm	3-10mm	10-50mm
1	1,51E-03	7,82E-04	4,50E-03
2	8,88E-04	4,17E-04	2,02E-04
3	2,14E-03	1,22E-03	7,50E-04

6.7 Result of Gas Dispersion Frequency

Gas Dispersion can be caused by gas leakage in the pipeline or other components. This work accident may occur if the gas condition flows under high pressure conditions. Damage caused by gas dispersion generally affects human health because the oxygen content is contaminated with gas leakage occurring. In term to define the frequency in each of event that caused as hazardous event so the calculation of process each bore then counted and had the result as shown below:

Table 6. 7 Result of Gas Dispersion Frequency per Bore Diameter

Node	Frequency of Gas Dispersion per-Bore Diameter		
	1-3mm	3-10mm	10-50mm
1	2,65E-03	1,03E-03	5,00E-04
2	5,94E-04	2,78E-04	5,90E-04
3	1,19E-03	5,59E-04	2,71E-04

6.8 Result of VCE Frequency

Pressurized gas in a closed containment system would hold a pressure more than the explosion point of mixture between air and Methane, the potential hazard has a possible frequency of explosion and shown as table below:

Table 6. 8 Result of Frequency of VCE per-Bore Diameter

Node	Frequency of VCE per-Bore Diameter	
	10-50mm	50-150mm
1	5,63E-04	-

6.9 Result of Pool Fire Frequency

In term to define the frequency in each of event that caused as fire accident so the calculation of process each bore then counted and had the result as shown below:

Table 6. 9 Result of Flash Fire Frequency per-Bore Diameter

Node	Frequency of Flash Fire per-Bore Diameter			
	1-3mm	3-10mm	10-50mm	50-150mm
1	1,20E-04	2,49E-04	1,20E-04	2,93E-05
2	7,17E-04	3,37E-04	1,63E-04	3,97E-05

6.10 Result of BLEVE Frequency

Fuel boil that is not accompanied by flame ignition is the main cause of the BLEVE. The characteristics of the occurrence of BLEVE generally have high temperature and long time duration. In term to define the frequency in each of event that caused as fire accident so the calculation of process each bore then counted and had the result as shown below:

Table 6. 10 Result of Flash Fire Frequency per-Bore Diameter

Node	Frequency of Flash Fire per-Bore Diameter			
	1-3mm	3-10mm	10-50mm	50-150mm
4	4,02E-04	8,29E-05	5,63E-04	9,76E-06
5	2,39E-04	1,12E-04	5,44E-05	1,32E-05

6.11 Result of Flash Fire Frequency

Gas leak that is not accompanied by flame ignition is the main cause of the Flash fire. The characteristics of the occurrence of flash fire generally have high temperature and short time duration. In term to define the frequency in each of event that caused as fire accident so the calculation of process each bore then counted and had the result as shown below:

Table 6. 11 Result of Flash Fire Frequency per-Bore Diameter

Node	Frequency of Flash Fire per-Bore Diameter			
	1-3mm	3-10mm	10-50mm	50-150mm
1	3,32E-04	1,29E-04	5,63E-04	-
2	3,98E-03	1,87E-03	3,98E-03	-
3	8,03E-03	3,78E-03	1,83E-03	-

CHAPTER VII

CONSEQUENCE ANALYSIS

7.1 Aerial Condition in ALOHA

Implementation of the consequences of fire analysis is influenced by temperature and wind direction at the location of the object to be analyzed. The direction of the arrival of the compass will determine where the direction of fire will develop and cause the imposition of fire on the direction of the direction of the wind direction whose speed depends on the wind speed and pressure acting on the system. The external temperature of the system will be able to affect the flux heat which causes the combustion speed and radiation from the system fluid, so that the temperature needs to be considered. This study found several conditions of wind direction and sea surface temperature, temperature and wind direction and speed obtained from the Indonesian Government's Meteorology, Climatology and Geophysics Agency data that is linked to the official website. The conclusions of some wind direction, speed and temperature conditions are made into a table in the following scenarios:

Table 7. 1 Atmospheric Data of Kolaka
(Source: BMKG Online Data)

No.	Cluster	Max Temperature	Average Moisture	Max Wind Velocity
1	MAX JAN TO MARCH	36,20	89,00	8,00
	AVRG. JAN TO MARCH	60,59	80,78	3,31
	MIN JAN TO MARCH	31,20	63,00	1,00
2	MAX APRIL TO JUNE	35,00	96,00	10,00
	AVRG. MARCH TO JUNE	33,05	82,11	3,05
	MIN APRIL TO JUNE	27,40	66,00	0,00
3	MAX JULY TO SEPT	36,80	89,00	7,00
	AVRG. JULY TO SEPT	33,77	69,71	4,46
	MIN JULY TO SEPT	30,00	51,00	0,00
4	MAX OCTOBER TO DEC	38,00	83,00	7,00
	AVERAGE OCT TO DEC	35,12	72,91	4,39
	MIN OCT TO DEC	32,40	56,00	3,00

This research is prioritized to detect and provide recommendations on the potential risks caused by fire accidents, one of which influences the direction of the compass. But because the existing data depicts wind that blows on the Kolaka region, Southeast Sulawesi, the mode data which is the most data emerged from January 1, 2019 to December 12, 2019, illustrated that there was no significant wind gust. Therefore, the authors assume the direction of the arrival of the wind with the second most data value after the mode and obtained the direction of the wind coming from east to southwest. From the data above, we could configure the consequence on aerial of impact, as we would determine from the ALOHA Software.

7.2 Result of ALOHA MODEL

ALOHA Fire modeling is a simple software that can describe the distribution of fire arising from an event or series of events. ALOHA will be able to provide an overview into several fire incidents including jet fire, flash fire, VCE, BLEVE and toxic gas dispersion. In this study, researchers focused on observations on jet fire, flash fire, VCE and gas dispersion which have identified the possibility of the occurrence of some of the above.

The jet fire depicted in ALOHA is a radius of the likelihood of a fire occurring in a form that can be described by ALOHA, with this limitation even though there is an atmospheric picture set by the researcher, the results appearing on the jet fire are the radius of the ability of the fire to reach an object, but do not represent direct aerial jet fire.

In addition, the limitation of ALOHA Fire Modeling Software is its radius in determining or identifying fires, ALOHA can only describe the radius scale in yards or miles, the scale is also limited in terms of detail. ALOHA cannot identify the likelihood of fire spread or radius if the results in the calculation analysis of the ALOHA software do not reach 10 yards or 9.14 meters.

7.2.1 Result of Jet Fire ALOHA Model

Jet fire as we could assume a pressurized fire that flows in leakage of pipe or instrument and with condition of cluster will shown as:

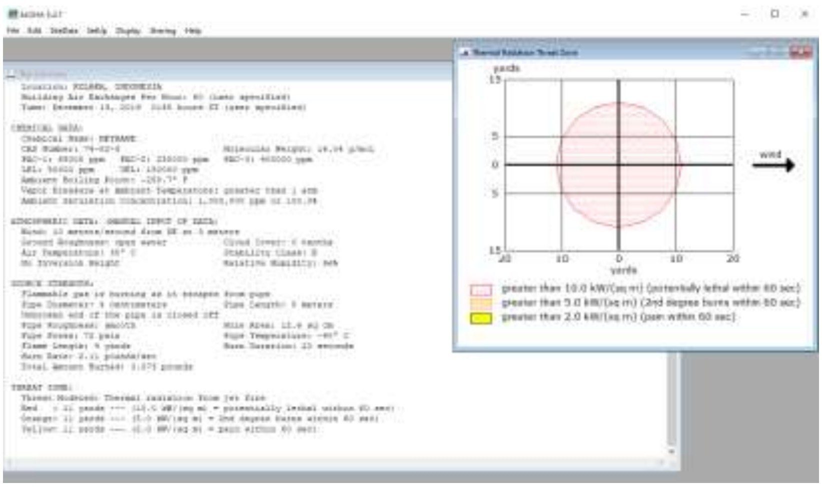


Figure 7. 1 Example Jet Fire on ALOHA

The display shows the area that occurs in jet-fire in ALOHA, but to simplify and draw conclusions that can be analyzed from the fatality of the system needs to be made researchers retract exploring in ALOHA into the depiction of existing system scenarios, or example jet-fire is the following: A jet fire is a pressurized stream of combustible gas or atomized liquid (such as a high-pressure release from a gas pipe or wellhead blow-out event) that is burning. If such a release is ignited soon after it occurs, the result is an intense jet flame

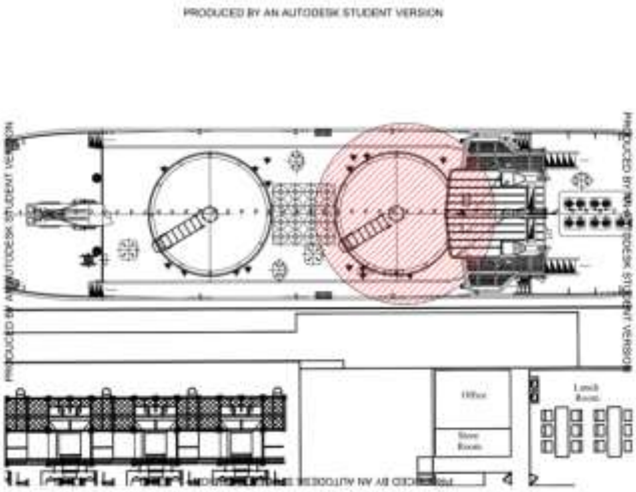


Figure 7. 2 Example of Jet Fire Layout

The result of jet fire analysis in consequence fire modeling of aloha indicates the lethal or red radius of happened in the Jet fire had a point in 11,11,11 miles.

7.2.2 Result of Flash Fire ALOHA Model

Flash Fire which is a fire incident caused by the mixing of methane content with air content to get an ignition point from the mixture of the two chemicals in the process without being pressured. Flash fire in ALOHA modeling emphasizes the radius of the likelihood of a fire that is not a direct impact or the impact of a fire burst, so that what is found in the description of ALOHA is the possible distribution and radius of the gas leak.Flash fire as we could assume a pressurized fire that flows in leakage of pipe or instrument and with condition of cluster will shown as:

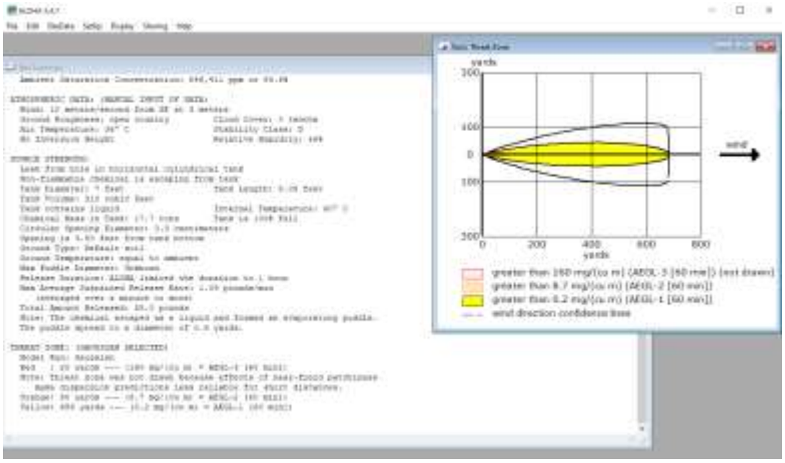


Figure 7. 3 Flash Fire on ALOHA

The display shows the area that occurs in flash-fire in ALOHA, but to simplify and draw conclusions that can be analyzed from the fatality of the system needs to be made researchers retract exploring in ALOHA into the depiction of existing system scenarios, for example flash-fire is the following:

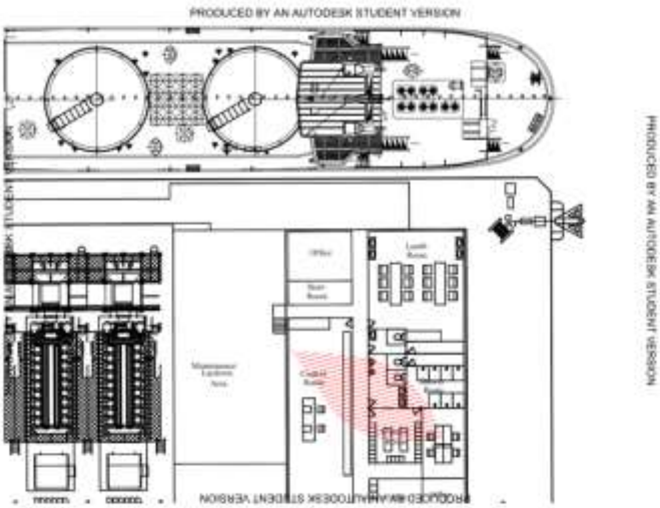


Figure 7. 4 Example of Flash Fire Layout

7.2.3 Result of VCE ALOHA Model

ALOHA fire modelling on the Vapour Cloud Explosion incident would show the possibility of areal within range to hit by the accident, the condition of accident would shown below:

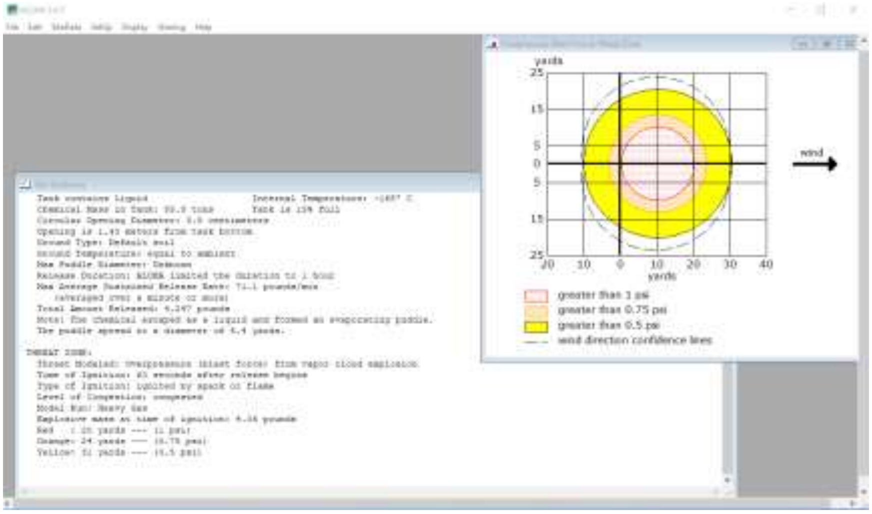


Figure 7. 5 Example of VCE ALOHA Model

The display shows the area that occurs in jet-fire in ALOHA, but to simplify and draw conclusions that can be analyzed from the fatality in accordance to GA:

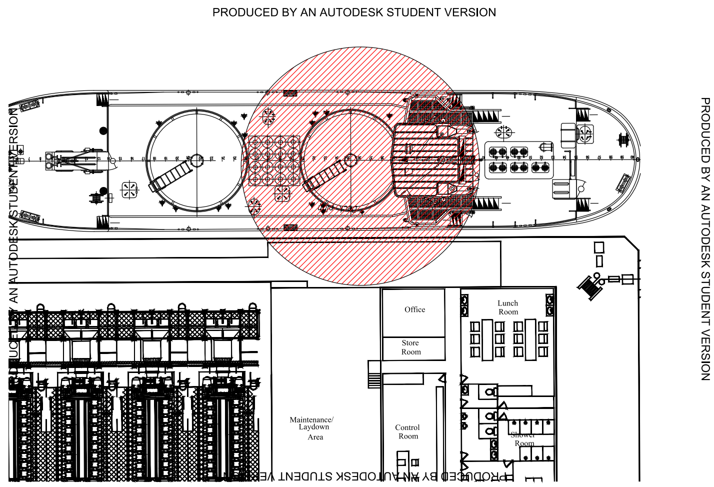
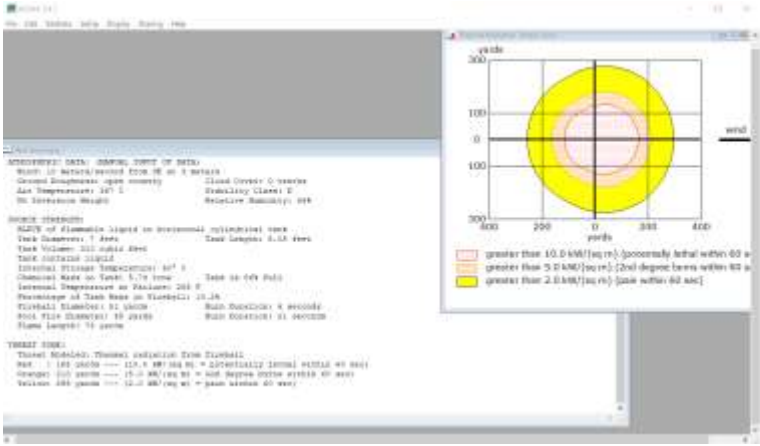


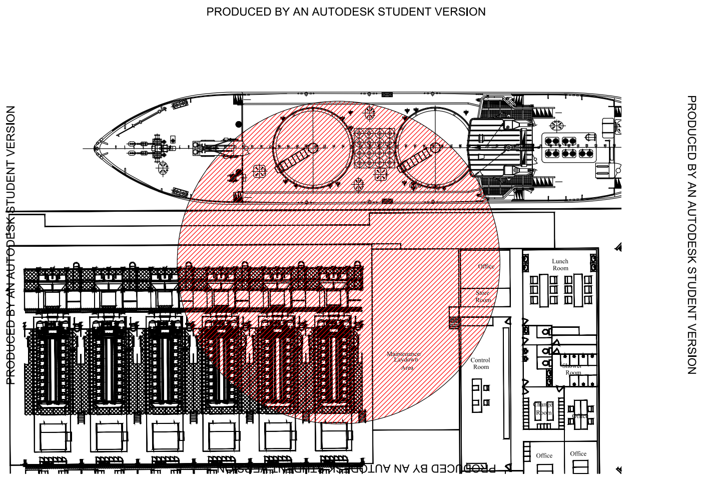
Figure 7. 6 Example of VCE Layout

7.2.4 Result of BLEVE ALOHA Model

BLEVE as we could assume leak of gas that flows in leakage of pipe or instrument and with condition of cluster will shown as:

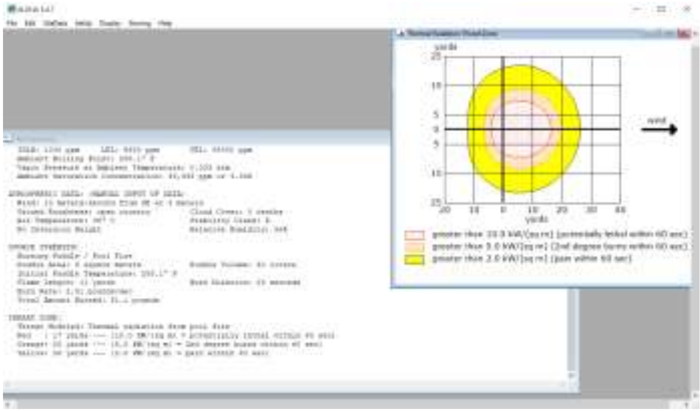


The display shows the area that occurs in jet-fire in ALOHA, but to simplify and draw conclusions that can be analyzed from the fatality in accordance to GA:

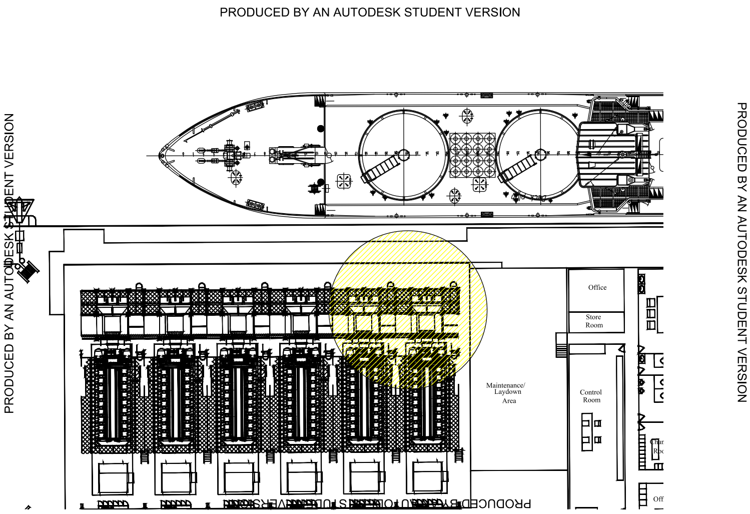


7.2.5 Result of Pool Fire ALOHA Model

Pool Fire as we could assume leak of gas that flows in leakage of pipe or instrument and with condition of cluster will shown as:



The display shows the area that occurs in jet-fire in ALOHA, but to simplify and draw conclusions that can be analyzed from the fatality in accordance to GA:



7.2.6 Result of Gas Dispersion ALOHA Model

Gas dispersion as we could assume leak of gas that flows in leakage of pipe or instrument and with condition of cluster will shown as:

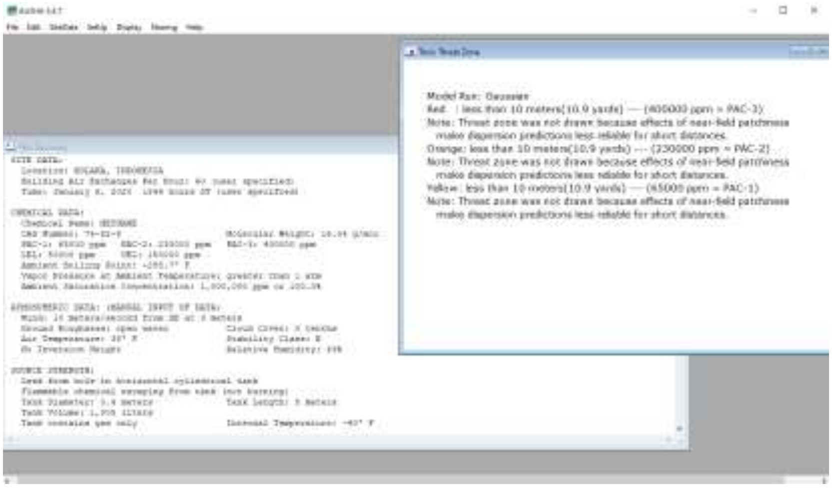


Figure 7. 7 Gas Dispersion on ALOHA System Analysis

7.3 Manning Scenario

In the initial explanation it was explained that the main impact of the fire incident was the people around it. Therefore, it is necessary to know the number of crew working at the FSRU or at BMPP at each work location, especially on the system being analyzed to determine the impact of each hazard event that occurs in accordance with the consequence analysis. Table shows the number of crews working on the FSRU and BMPP.

Table 7. 2 Manning Scenario

Node	Receiver	Crew Count
1	LNG Pump Room	2
2	Flexible Hose	3
3	Gas Valve Unit	2
4, 5	Engine Control Room	6
Total Crew		13

The consideration of determining the manning scenario analyzed in this study is based on regulations governing the number of crews on the ship and also with expert. In the LNG Pump room will be prepared at the time of initiation and checking before starting and at the time of stopping the system are 2 people on guard. In the flexible hose unit, flexible hose installation is carried out by each of the three crews on each ship that is conducting ship-to-ship bunkering. But when the transfer process took place only 3 people were alerted in total as the supervisor of the proceedings and the prevention of unnatural events from flexible hose that could be seen in plain view. The Gas Valve Unit is a series of safety pipe valve systems in the Natural Gas transfer process, when the system operates, there must be a supervisor on standby to be able to know the performance of the GVU both up close and at a certain perimeter and be alerted by two people for it. Engine Control Room at BMPP is the most crucial thing as a place to control and control the equipment in the Engine Room as well as the fuel transfer system in BMPP itself with crew status who are alert according to the expertise of each of six people.

7.4 Result of Jet Fire Consequence Analysis

Jet Fire is one of the consequences that results in the system being analyzed. In analyzing the consequences using fire modeling software, input of event data is needed so that the consequence analysis results are more accurate. Scenarios for consequence analysis Examples of input data for jet fire as shown.

Table 7. 3 Process Condition of Jet Fire Consequence Analysis

Process Condition	
Temperature	Minus 50 C
Pressure	5 Bar
Pipe	
Pipe Length	8 meter
Pipe Diameter	40 mm
Weather	
Wind Direction	SE
Time of Day	Day
Cloud Condition	Bright

Table above is the recapitulation of the jetfire consequences analysis at each node and the leak scenario that has been determined using day time and night time conditions using fire modeling software for societal risk in the FSRU.

Table 7. 4 Result of Jet Fire Consequence Analysis

Cluster	Max Temperature	Average Moisture	Max Wind Velocity	Consequence each Bore Scenario (Red, Orange, Yell) (Yards)			Node
				3 mm	10 mm	35 mm	
1	36,20	63,00	8,00	N/A	N/A	11, 11, 11	Node 2
	33,20	80,78	3,31	N/A	N/A	11, 11, 11	
	31,20	89,00	1,00	N/A	N/A	11, 11, 11	
2	35,00	66,00	10,00	N/A	N/A	11, 11, 11	
	33,05	82,11	3,05	N/A	N/A	11, 11, 11	
	27,40	96,00	0,00	N/A	N/A	11, 11, 11	
3	36,80	51,00	7,00	N/A	N/A	11, 11, 11	
	33,77	69,71	4,46	N/A	N/A	11, 11, 11	
	30,00	89,00	0,00	N/A	N/A	11, 11, 11	
4	38,00	56,00	7,00	N/A	N/A	11, 11, 11	
	35,12	72,91	4,39	N/A	N/A	11, 11, 11	
	32,40	86,00	3,00	N/A	N/A	11, 11, 11	

7.5 Result of VCE Consequence Analysis

Vapour Cloud Explo is one of the consequences that results in the system being analyzed. In analyzing the consequences using fire modeling software, input of event data is needed so that the consequence analysis results are more accurate. Scenarios for consequence analysis Examples of input data for jet fire as shown.

Table 7. 5 Process Condition of VCE Consequence Analysis

Process Condition	
Temperature	Minus 165 C
Pressure	3 Bar
Pipe	
Pipe Length	12 meters
Pipe Diameter	40 mm
Weather	
Wind Direction	SE
Time of Day	Day
Cloud Condition	Bright

The recapitulation of the jetfire consequences analysis at each node and the leak scenario that has been determined using daytime and nighttime conditions using fire modeling software for societal risk in the FSRU to BMPP.

Table 7. 6 Result of VCE Consequence Analysis

Cluster	Max Temperature	Average Moisture	Max Wind Velocity	Consequence Each Bore Scenario (Red, Orang, Yellow) (Yards)			
				3 mm	10 mm	35 mm	Node
1	36,20	63,00	8,00	N/A	N/A	20, 25, 30	Node 1
	33,20	80,78	3,31	N/A	N/A	20, 25, 30	
	31,20	89,00	1,00	N/A	N/A	20, 25, 30	
2	35,00	66,00	10,00	N/A	N/A	20, 25, 30	
	33,05	82,11	3,05	N/A	N/A	20, 25, 30	
	27,40	96,00	0,00	N/A	N/A	20, 25, 30	
3	36,80	51,00	7,00	N/A	N/A	20, 25, 30	
	33,77	69,71	4,46	N/A	N/A	20, 25, 30	
	30,00	89,00	0,00	N/A	N/A	20, 25, 30	
4	38,00	56,00	7,00	N/A	N/A	20, 25, 30	
	35,12	72,91	4,39	N/A	N/A	20, 25, 30	
	32,40	86,00	3,00	N/A	N/A	20, 25, 30	

7.6 Result of Flash Fire Consequence Analysis

Flash Fire is one of the consequences that results in the system being analyzed. In analyzing the consequences using fire modeling software, input of event data is needed so that the consequence analysis results are more accurate. Scenarios for consequence analysis Examples of input data for flash fire as shown.

Table 7. 7 Flash Fire Process Condition Consequence Analysis

Process Condition	
Temperature	-40 C
Pressure	5 Bar
Pipe	
Pipe Length	8 meters
Pipe Diameter	40 mm
Weather	
Wind Direction Time of Day	SE Day
Cloud Condition	Bright

The recapitulation of the flash fire consequences analysis at each node and the leak scenario that has been determined using daytime conditions using ALOHA for societal risk in the BMPP Storage Tank to BMPP Daytank.

Table 7. 8 Result of Flash Fire Consequence Analysis

Cluster	Max Temperature	Average Moisture	Max Wind Velocity	Consequence Each Bore Scenario (Red, Orang, Yellow) (Yards)			Node
				3 mm	10 mm	35 mm	
1	36,2	63	8	N/A	N/A	20, 90, 686	Node 1
	33,2	80,78	3,31	N/A	N/A	18, 80, 658	
	31,2	89	1	N/A	N/A	13, 72, 635	
2	35	66	10	N/A	N/A	19, 88, 680	
	33,05	82,11	3,05	N/A	N/A	18, 80, 658	
	27,4	96	0	N/A	N/A	13, 72, 635	
3	36,8	51	7	N/A	N/A	20, 90, 686	
	33,77	69,71	4,46	N/A	N/A	18, 80, 658	
	30	89	0	N/A	N/A	13, 72, 635	
4	38	56	7	N/A	N/A	22, 94, 691	
	35,12	72,91	4,39	N/A	N/A	18, 80, 658	
	32,4	86	3	N/A	N/A	13, 72, 635	
4	38	56	7	N/A	N/A	22, 94, 691	
	35,12	72,91	4,39	N/A	N/A	18, 80, 658	
	32,4	86	3	N/A	N/A	13, 72, 635	

7.7 Result of BLEVE Consequence Analysis

BLEVE is one of the consequences that results in the system being analyzed. In analyzing the consequences using fire modeling software, input of event data is needed so that the consequence analysis results are more accurate. Scenarios for consequence analysis Examples of input data for flash fire as shown.

Table 7. 9 BLEVE Process Consequence Analysis Condition

Process Condition	
Temperature	40
Pressure	3 Bar
Pipe	
Pipe Length	30meters
Pipe Diameter	125 mm
Weather	
Wind Direction	SE
Time of Day	Day
Cloud Condition	Bright

The recapitulation of the flash fire consequences analysis at each node and the leak scenario that has been determined using daytime conditions using ALOHA for societal risk in the BMPP Storage Tank to BMPP Daytank.

Table 7. 10 BLEEVE Result Consequence Analysis

Cluster	Max Temperature	Average Moisture	Max Wind Velocity	Consequence Each Bore Scenario (Red, Orang, Yellow) (Yards)			Node
				3 mm	10 mm	35 mm	
1	36,2	63	8	N/A	N/A	34, 60, 97	Node 4
	33,2	80,78	3,31	N/A	N/A	34, 60, 97	
	31,2	89	1	N/A	N/A	34, 60, 97	
2	35	66	10	N/A	N/A	34, 60, 97	
	33,05	82,11	3,05	N/A	N/A	34, 60, 97	
	27,4	96	0	N/A	N/A	34, 60, 97	
3	36,8	51	7	N/A	N/A	34, 60, 97	
	33,77	69,71	4,46	N/A	N/A	34, 60, 97	
	30	89	0	N/A	N/A	34, 60, 97	
4	38	56	7	N/A	N/A	34, 60, 97	
	35,12	72,91	4,39	N/A	N/A	34, 60, 97	
	32,4	86	3	N/A	N/A	34, 60, 97	
4	38	56	7	N/A	N/A	34, 60, 97	
	35,12	72,91	4,39	N/A	N/A	34, 60, 97	
	32,4	86	3	N/A	N/A	34, 60, 97	

7.8 Result of Pool Fire Consequence Analysis

Pool Fire is one of the consequences that results in the system being analyzed. In analyzing the consequences using fire modeling software, input of event data is needed so that the consequence analysis results are more accurate. Scenarios for consequence analysis Examples of input data for pool fire as shown.

Table 7. 11 Pool Fire Process Condition

Process Condition	
Temperature	40
Pressure	3 Bar
Pipe	
Pipe Length	30meters
Pipe Diameter	125 mm
Weather	
Wind Direction	SE
Time of Day	Day
Cloud Condition	Bright

The recapitulation of the pool fire consequences analysis at each node and the leak scenario that has been determined using daytime conditions using ALOHA for societal risk in the BMPP Storage Tank to BMPP Daytank.

Table 7. 12 Pool Fire Consequence Result

Cluster	Max Temperature	Average Moisture	Max Wind Velocity	Consequence Each Bore Scenario (Red, Orang, Yellow) (Yards)			Node
				3 mm	10 mm	35 mm	
1	36,2	63	8	N/A	N/A	17, 20, 26	Node 4
	33,2	80,78	3,31	N/A	N/A	16, 18, 26	
	31,2	89	1	N/A	N/A	15, 18, 26	
2	35	66	10	N/A	N/A	17, 20, 26	
	33,05	82,11	3,05	N/A	N/A	16, 18, 26	
	27,4	96	0	N/A	N/A	15, 18, 26	
3	36,8	51	7	N/A	N/A	17, 20, 26	
	33,77	69,71	4,46	N/A	N/A	16, 18, 26	
	30	89	0	N/A	N/A	15, 18, 26	
4	38	56	7	N/A	N/A	17, 20, 26	
	35,12	72,91	4,39	N/A	N/A	16, 18, 26	
	32,4	86	3	N/A	N/A	15, 18, 26	
4	38	56	7	N/A	N/A	17, 20, 26	
	35,12	72,91	4,39	N/A	N/A	16, 18, 26	
	32,4	86	3	N/A	N/A	15, 18, 26	

7.9 Result of Gas Dispersion Consequence Analysis

Gas Dispersion is one of the consequences that results in the system being analyzed. In analyzing the consequences using fire modeling software, input of event data is needed so that the consequence analysis results are more accurate. Scenarios for consequence analysis Examples of input data for flash fire as shown.

Table 7. 13 Process Condition on Gas Dispersion Consequence Analysis

Process Condition	
Temperature	-40 C
Pressure	5 Bar
Pipe	
Pipe Length	8 meters
Pipe Diameter	40 mm
Weather	
Wind Direction	SE
Time of Day	Day
Cloud Condition	Bright

The results of the analysis of the consequences caused by gas dispersion with ALOHA are categorized as consequences that can be accepted with consideration of ALOHA unable to describe the effect of distance from natural gas leakage on a scale of 6000 ppm with a limit of ALOHA is 10 meters is the minimum consequence of this software analysis. While the strength that ALOHA can show in describing gas leakage is 2 meters in 1 minute.

CHAPTER VIII

Results of Risk Assessment

8.1 Overview Steps for Risk Assessment

Describing the values of each consequence obtained by the extent of the fire that occurs when an accident in the modeling of Event Tree Analysis. In the modeling taken with ETA there are 3 models obtained and plotted according to GA in the system scenarios studied. In this case the removal or refueling with LFO and natural gas at BMPP. Each modeling with ETA which is described in Jet fire, Flash Fire and Gas Dispersion which has been determined by the frequency of events with the FTA calculation then models each of these fire events with the existing scenarios.

Since the modeling is complete, the possibility of fatality is obtained by placing the fire modeling and its distribution into the GA scenario. The fatality is then graphed as the x-axis where the y-axis is the frequency of likelihood of events obtained from ETA from each fire modeling that occurs.

In this research, we will show each scenario that might occur while still using the frequency probability that occurs from each fire model in ETA and varying the atmospheric data that has been historically applicable. Until the data obtained will be derived in each fire model.

8.2 Result of Jet Fire F-N Curves

Jet fire is one of the fires that can occur in the BMPP fuel supply system with a fire that is described to occur in the presence of gas leakage with temperature and pressure and chemical composition that is ready to burn when exiting the system.

These table shown the data of that accumulatively described in table of Jet fire as cluster 1:

Table 8. 1 Jet Fire F-N Curve Table

Jet Fire 10-50mm Cluster 1			
NODE	Frequency	Cumulative Freq.	Fatalities
1	4,50E-03	4,50E-03	2
2	2,46E-05	4,52E-03	1
3	6,20E-06	4,53E-03	4
4	4,35E-03	8,88E-03	2
5	4,47E-03	1,34E-02	2

Data that has been analyzed previously obtained a description of the position of the consequences and frequency of accidents described in the f-N Curve as follows:

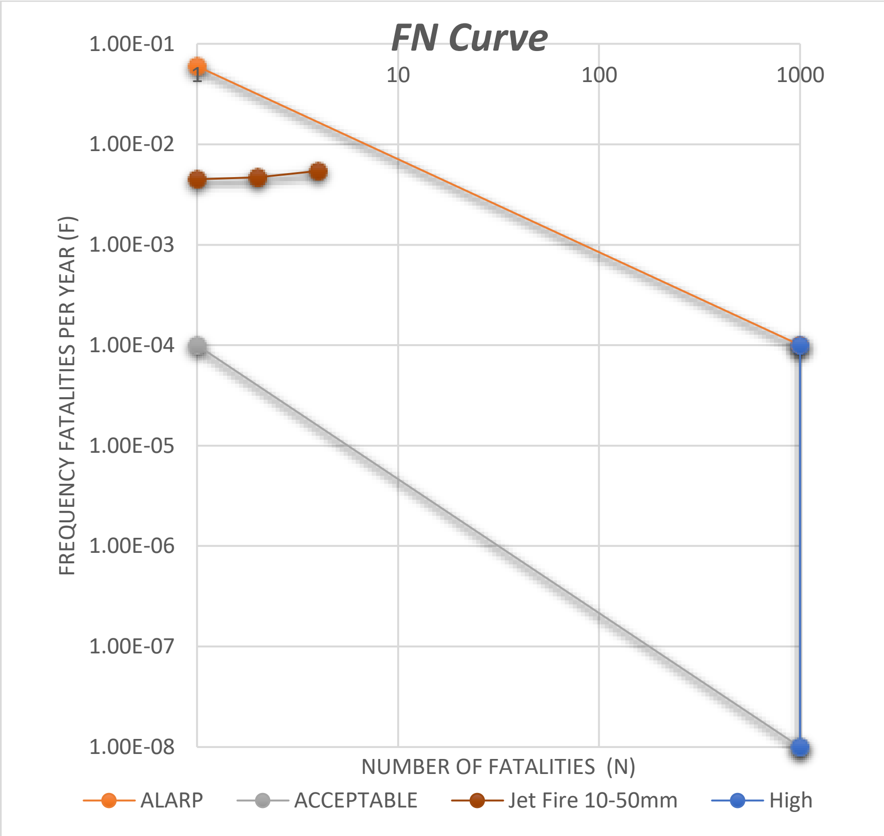


Figure 8. 1 Risk Result of FN Curve in Jet Fire

8.3 Result of Flash Fire FN Curves

Flash fire is the result of combustion that occurs when VCE from the form of combustible material is released into the open air. The main danger in this combustion is thermal radiation and direct flame contact from the incident. Fires that occur in the form of flash fire in just a few moments so that the total radiation exposed to other objects in the vicinity of the flash fire is much lower than the case of direct fire.

In this study, the flash fire model was mapped to each incident of the instrument that could cause the occurrence of each nodes which was then described in frequency. The frequency is then calculated by the severity of the impact on death to humans that is around the event so that it is illustrated with the following graph:

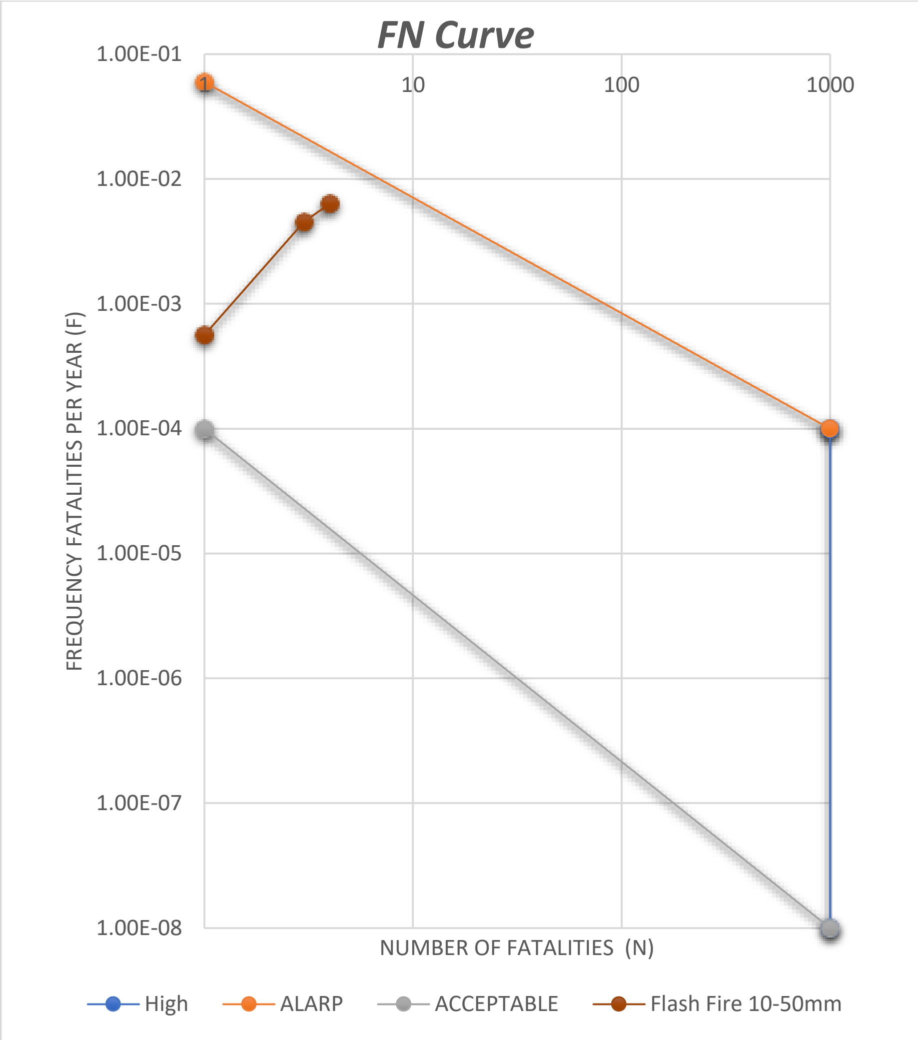


Figure 8. 2 Risk Result of FN Curve in Flash Fire

These curves had gotten from the data that accumulatively described in table of Jet fire as cluster 1:

Table 8. 2 Flash Fire F-N Curve Table

Flash Fire 10-50mm			
NODE	Frequency	Cumulative Frequency	Fatalities
1	5,07E-03	5,07E-03	3
2	1,66E-03	6,73E-03	1
3	4,18E-03	1,09E-02	4
4	2,93E-03	1,38E-02	1
5	3,02E-03	1,69E-02	1

8.4 Result of Vapour Cloud Explosion F-N Curve

The following is a recapitulation of the results of frequency, cumulative frequency along with fatalities which are the result of the consequence analysis on the explosion scenario for each outcome

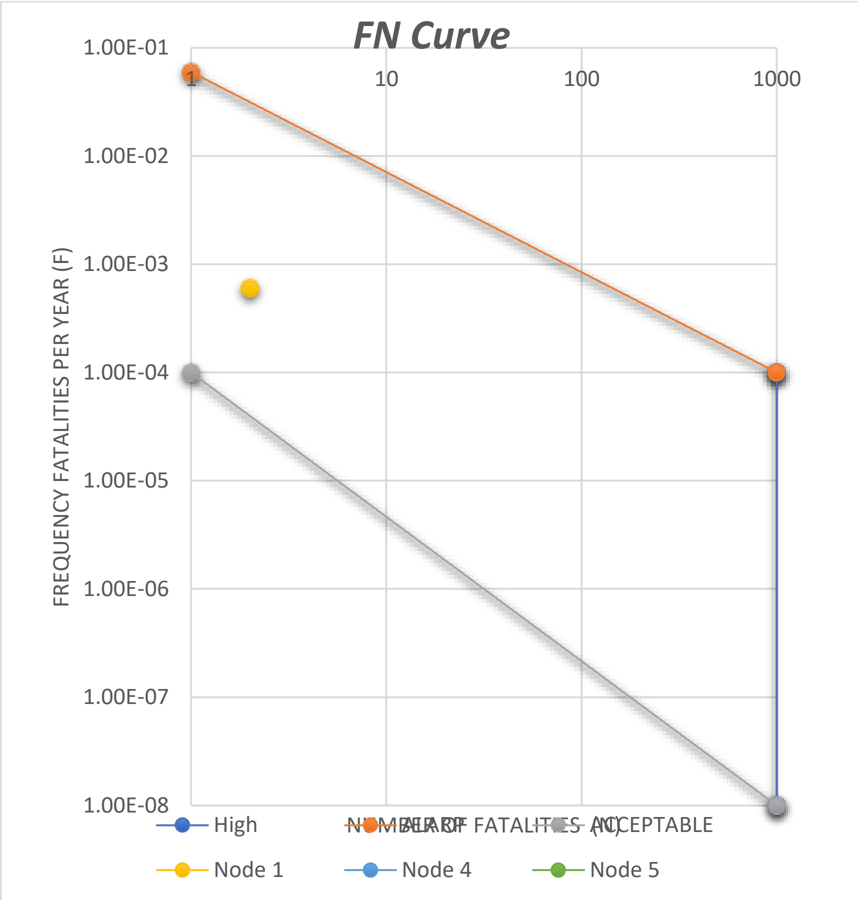


Figure 8. 3 Risk Result of FN Curve in VCE

These curves had gotten from the data that accumulatively described in table of VCE as cluster 1:

Table 8. 3 Table of VCE F-N Curve

VCE 10-50mm		
NODE	Frequency	Fatalities
1	5,62E-04	2

8.5 Result of Pool Fire FN Curve

As Fuel puddle in sludge or any circumstances and get heated in time to achieve boiling point of the fuel oil, then the fuel oil would burn and caused pool fire, the, graph of pool fire FN curve would be shown below:

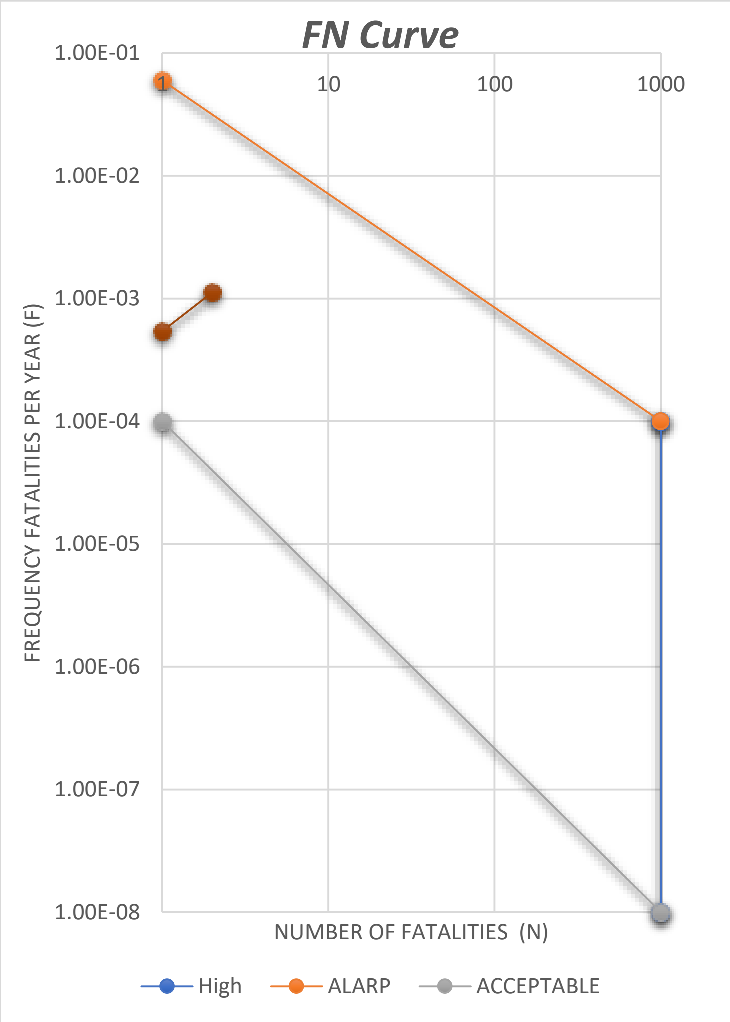


Figure 8. 4 FN Curve of Pool Fire 10-50mm

These curves had gotten from the data that accumulatively described in table of Pool Fire as cluster 1:

Table 8. 4 Table of FN Curve Pool Fire Graph

Pool Fire 10-50mm			
NODE	Frequency	Cumulative Frequency	Fatalities
4	5,42E-04	5,42E-04	1
5	5,84E-04	1,13E-03	2

8.6 Result of BLEVE F-N Curve

Fuel reacts to the boiling with heat treatment to the fuel and causing fuel into their boiling point and comes up with highly pressurized tank and caused an explosion, as the result of FN curve are shown in figure below:

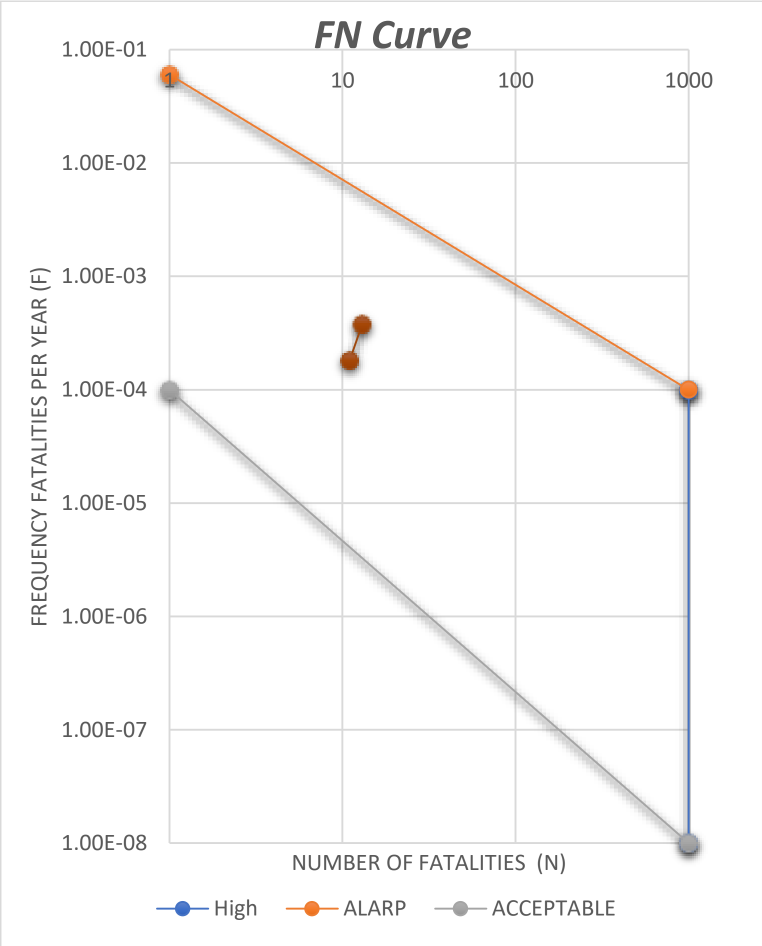


Figure 8. 5 BLEVE FN Curve Result

These curves had gotten from the data that accumulatively described in table of BLEVE as cluster 1:

Table 8. 5 BLEVE Data of graphic

BLEVE 10-50mm			
NODE	Frequency	Cumulative Frequency	Fatalities
4	1,81E-04	1,81E-04	11
5	1,97E-04	3,78E-04	13

8.7 Result of Gas Dispersion F-N Curve

Gas dispersion has several special types that need to be considered in terms of the molecular density of the gas. This research analyzes natural gas which has a bouyant type of gas that is 2% less dense than air, so gas dispersion is said to be light and rise naturally.

The gas reacts in an identical manner until the relative motion of the gas cloud increases, producing turbulence around the gas area that exits the system resulting in a fast mixture of gas and air. The graph which illustrates whether the accident is still within reasonable limits or not to observe the effects on human mortality, to obtain the following graph:

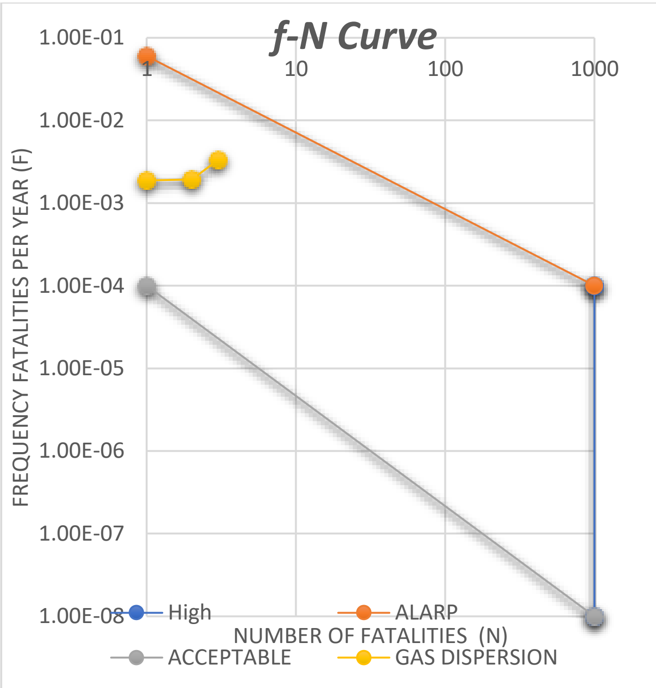


Figure 8. 6 Risk Result of FN Curve in Gas Dispersion

These curves had gotten from the data that accumulatively described in table of Gas Dispersion as cluster 1:

Table 8. 6 Table of Gas Dispersion F-N Curve 10-50mm

Jet Fire 10-50mm			
NODE	Frequency	Cumulative Frequency	Fatalities
1	1,88E-03	1,88E-03	1
2	5,54E-05	1,93E-03	1
3	1,39E-03	3,32E-03	1

8.8 Layer of Protection Analysis

Mitigation recommendations are carried out in each node's hazard scenario. Mitigation recommendations are carried out to reduce the value of the frequency of events by adding safeguards according to the IPL standard on the LOPA so that the value of the risk level from unacceptable risk or ALARP becomes an acceptable.

8.5.1 Layer of Protection Analysis Result

For example, shown of mitigation recommendations on node 1 scenario 10-50 for flash fire events in the form of the addition of a temperature alarm. The addition of these components reduces risk from unacceptable risk to transition risk or acceptable risk and available on the LOPA worksheet as follows.

Table 8. 7 LOPA Result Node 1 Flash Fire

Scenario Number: Cluster 1	Node: 1	Scenario Title: Flash Fire Consequence on Node 1 Cluster 1	
Date	Description	Probability	Frequency (per Year)
Consequence Description/Category	Release of natural gas due to gas leakage and failure of system with potential for ignition and fatality		
Risk Tolerance Criteria (Category or Frequency)	Maximum Tolerable Risk of Fatal Injury		1,00E-04
Initiating Event (typically a frequency)	System Leakage and Failure		7,50E-03
Conditional Modifiers	Immediate Ignition	4,50E-03	
	VCE	5,63E-04	
	Flash Fire	5,63E-04	
	No Ignition	1,88E-04	
Frequency Unmitigated Consequence			5,63E-04
Independent Protection Layer (IPL)	Temperature Alarm	1,00E-02	
Total IPL Frequency			1,00E-02
Frequency of Mitigated Consequence			5,63E-06
Action Required to Meet Risk Tolerance Criteria	Recommended to add instrument Temperature Alarm to prevent incident		

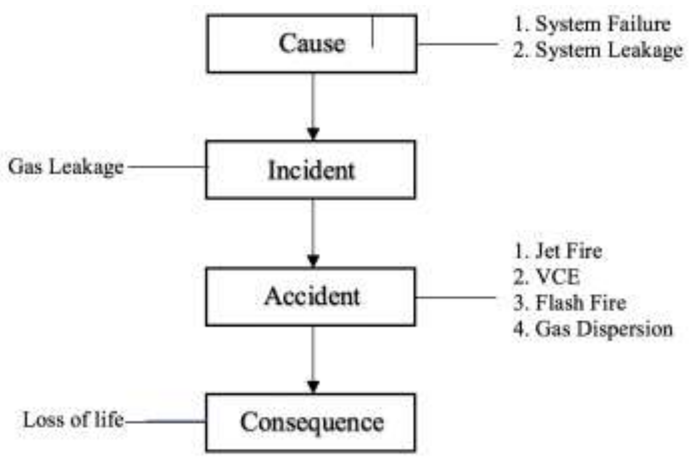
Mitigation recommendations given include the addition of a pressure alarm. The probability of an IPL failure or probability of failure on demand (PFD) is obtained from CCPS-Guidelines. The addition for an example of Vapour Cloud Explosion Accident from the analysis of these components reduces risk from unacceptable risk to transition risk or acceptable risk and available on the LOPA worksheet as follows.

Table 8. 8 LOPA Result Node 1 VCE

Scenario Number: Cluster 1	Node: 1	Scenario Title: VCE Consequence on Node 1 Cluster 1	
Date	Description	Probability	Frequency (per Year)
Consequence Description/Category	Release of natural gas due to gas leakage and failure of system with potential for ignition and fatality		
Risk Tolerance Criteria (Category or Frequency)	Maximum Tolerable Risk of Fatal Injury		1,00E-04
Initiating Event (typically a frequency)	System Leakage and Failure		7,50E-03
Conditional Modifiers	Immediate Ignition	4,50E-03	
	VCE	5,63E-04	
	Flash Fire	5,63E-04	
	No Ignition	1,88E-04	
Frequency Unmitigated Consequence			5,63E-04
Independent Protection Layer (IPL)	Pressure Alarm	1,00E-02	
Total IPL Frequency			1,00E-02
Frequency of Mitigated Consequence			5,63E-06
Action Required to Meet Risk Tolerance Criteria	Recommended to add instrument Pressure Alarm to prevent incident		

The LOPA sheet would conclude on all of the result, reasons behind is the result of risk assessment on the system with F-N Curve is all in condition of ALARP and to be considered in adding instrument of certain IPL in each of the condition applied.

8.9 Acceptable Cost of Mitigation



From the FSA's Guidelines as a useful tool in identificating possible risk reduction measures is the development of the causal chain. The identification of possible risk has already determined in the Chapter 5 to Chapter 6. In this chapter of research, we shall express the causal chains to simplify the identification, causal chain can be expressed as follows:

"A" sign in the figure representing the instrument mitigation of this research recommend as determined in LOPA Sheet to reduce the risk from ALARP into tolerable risk of F-N Curve such an example of instrument as gas detector alarm, automated fire safety alarm, temperature alarm.

The determination of risk reduction in layer of protection analysis then thorough the analysis of cost-benefit structure as if it does a significant effect or else. The cost benefit structure described in this research to have an assumption of past planned construction of the system and added by the cost of mitigational instrumentation as described on pharagraph before.

From the table of calculation to determine GCAF and NCAF, all of it shall shown the result whether the calculation of cost averted fatalities could be tolerated or should not have been added by additional instrument to mitigate the ALARP conditions. To have a summary of the calculation, researcher shall show the amount of GCAF in every mitigation allowance in the risk assessment.

One example of how this can be done will be given using one of the criteria that are proposed by the IMO [MSC 78/19/2]. According to the following table [Table 7-3] in order to recommend a Risk Control Option for implementation this must give a CAF less than $ 3 million.

Table 8. 9 Calculation Factor Table of GCAF

Scenario: 10-50mm	Flash Fire Node 1 scenario 10-50mm	Case 1
Description	Value	Symbol
Risk Reduction in Flash Fire case in node 1 scenario 10-50mm	4,63E-04	△R
Cost US$		
Additional Gas Detector Alarm cost	450	△C
GCAF	9,72E+05	Accepted
Compensation of Life Loss per year US$		
BLL	1,00E+06	
Fatality	3	
NCAF	-6,48E+09	

Gross Cost Averting a Fatality formula:

$$GCAF = \frac{\Delta C}{\Delta R}$$

Net Cost of Averting a Fatality formula:

$$NCAF = \frac{\Delta C - \Delta B}{\Delta R}$$

ΔC is the cost per ship of the risk control option
ΔB is the economic benefit per ship resulting from the implementation of the RCO
ΔR is the risk reduction per ship, in terms of the number of fatalities averted, implied by the risk control option

The value of cost per ship of the risk control option would be described as an assumption of market price for the instrument as table shown below:

Table 8. 10 Cost of Instrument Table

Cost of Instrument	
Instrument	Cost ($)
Temperature Alarm	190
Gas Detector Alarm	450
Pressure Alarm	250

In writing this thesis, the author defines delta C as the cost of the instrument added to a node in certain accident conditions. The value of delta R is the value obtained from the difference between the specific accident triggering state and the maximum tolerable risk or acceptable risk value on the F-N Curve.

In calculations involving fatalities from accidents illustrated by a person's death, the benchmark cost is 1M $ per life per year (Kontovas, 2005). The calculation of mitigation in each node of each accident then counted as the formula of GCAF and NCAF as a table perform in page 75, then as the summary if result, table below shown the summary of calculation in each of every case. Each of case was meant to be the mitigation of each additional instrument as a recommendation to prevent any accident that had been analyzed. These calculations could simply be derivative to cost of fatalities as we paid the amount of money for the safety of our crew and another people near the facility. Although in each country shall have the different in the amount of benefit or delta b. Benefit shall have explained and examined by the gross domestic product of a country that already have separating the amount of money for a minimum cost of life insurance as a payment or a guarantee for life that had to be in danger in the country.

Table 8. 11 Result of Flash Fire CAF

Flash Fire Scenario of Mitigation	△R	△C	△B	GCAF ($)	NCAF ($)
Case 1	5,E-04	5,E+02	1,E+06	1,E+06	-6,E+09
Case 2	2,E-03	2,E+02	1,E+06	1,E+05	-6,E+08
Case 3	4,E-03	5,E+02	1,E+06	1,E+05	-7,E+08
Case 4	2,E-04	2,E+02	1,E+06	8,E+05	-4,E+09
Case 5	2,E-04	2,E+02	1,E+06	8,E+05	-4,E+09
Case 6	4,E-05	2,E+02	1,E+06	5,E+06	-3,E+10

Table 8. 12 Result of VCE CAF

VCE Scenario of Mitigation	△R	△C	△B	GCAF ($)	NCAF ($)
Case 1	5,E-04	3,E+02	1,E+06	5,E+05	-6,E+09
Case 2	2,E-03	3,E+02	1,E+06	2,E+05	-6,E+08
Case 3	4,E-03	3,E+02	1,E+06	6,E+04	-7,E+08
Case 4	2,E-04	3,E+02	1,E+06	1,E+06	-4,E+09
Case 5	2,E-04	3,E+02	1,E+06	1,E+06	-4,E+09
Case 6	4,E-05	3,E+02	1,E+06	7,E+06	-3,E+10

Table 8. 13 Result of Jet Fire CAF

Jet Fire Scenario of Mitigation	△R	△C	△B	GCAF ($)	NCAF ($)
Case 1	4,E-03	3,E+02	1,E+06	6,E+04	-7,E+08
Case 2	1,E-04	3,E+02	1,E+06	2,E+06	-7,E+09
Case 3	5,E-04	3,E+02	1,E+06	5,E+05	-6,E+09
Case 4	3,E-03	3,E+02	1,E+06	1,E+05	-4,E+08
Case 5	3,E-03	3,E+02	1,E+06	1,E+05	-4,E+08
Case 6	2,E-04	3,E+02	1,E+06	1,E+06	-5,E+09
Case 7	2,E-04	3,E+02	1,E+06	1,E+06	-5,E+09

From graphic below we could conclude the acceptable and unacceptable cost of safety additional in terms of modifying the result of F-N Curve in each of node on the potential fire as shown in table 8.9 until 8.11.

So the criteria and the value of GCAF in mitigation in this study will show the following graph:

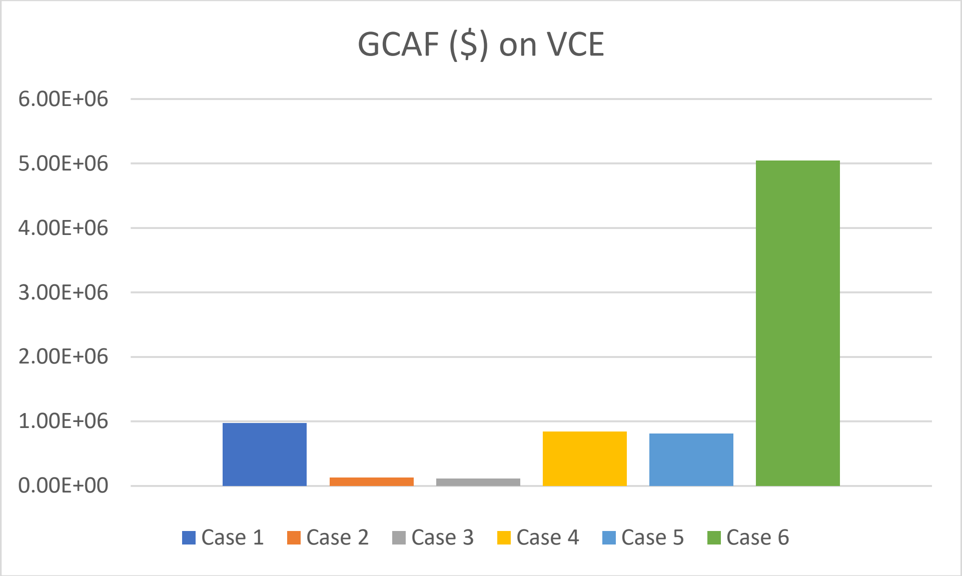


Figure 8. 7 GCAF on VCE

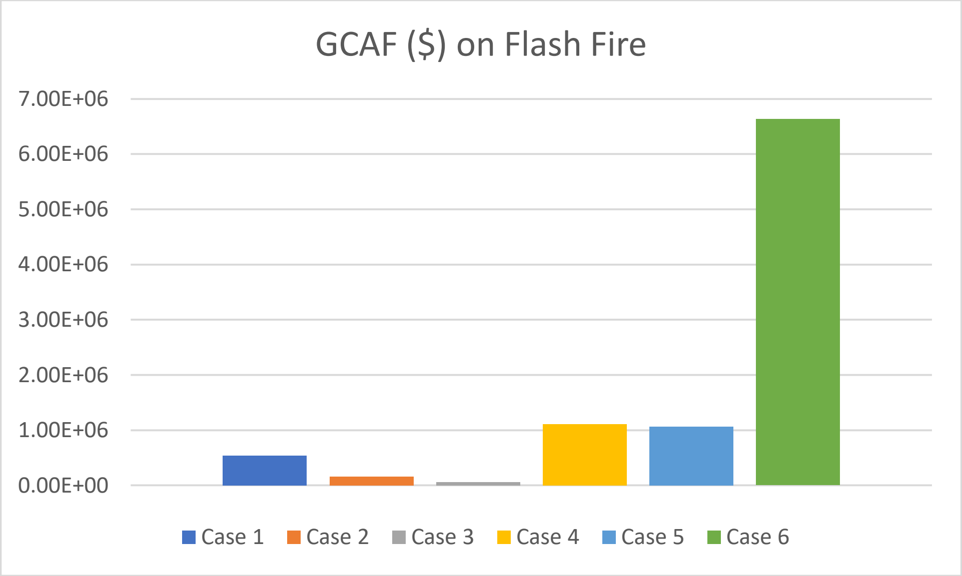


Figure 8. 8 GCAF on Flash Fire

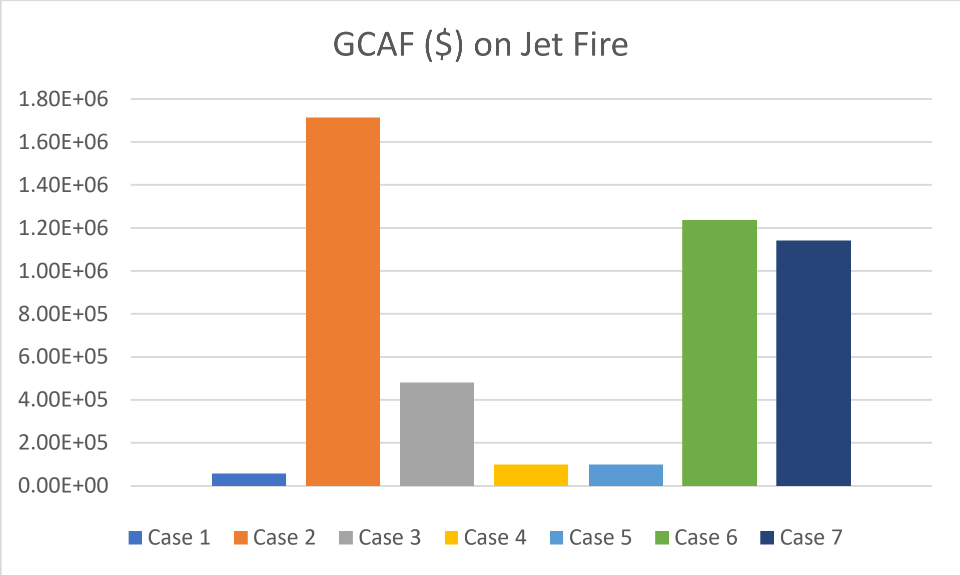


Figure 8. 9 GCAF on Jet Fire

The picture on the graph shows the cost value of each case of mitigation in each of the fire accident details. On the VCE chart and also the Flash fire graph, case 6 is the highest ordinary case where this case illustrates the allowance of the costs used for safety for the crew and the people around it cannot be recommended because the costs incurred are too much compared to the frequency of fatality. can be anticipated. Case 6 is a representation of node 4 with a diameter of 50 to 150 mm in the transfer of fuel oil from the BMPP Storage Tank to the Daily Fuel Oil Tank.

Whereas in the GCAF jet fire graphic figure, the highest price is issued in case two, where this case represents a leak hole with a diameter of 10-50 that is in the process or node of natural gas transfer from the heat exchanger or regasification unit until after going through a flexible hose. For risks that are set at this node is too small a risk of a reduction from the existing risk to be paid in large costs. Case 6 is still within a distance that is considered too much to be incurred because the costs incurred for adding instruments are too high compared to the risk reduction in this case. Then the table below shows the results of the GCAF whether acceptable or not, the receipt of Gross Cost Converted Fatality is then taken into consideration recommendations in research or research that requires material regarding the recommendation of adding instruments to the BMPP fuel supply with dual fuel engines at 60 MW capacity. If it can be concluded, the recommendation that can most be used as an addition to the BMPP fuel supply system is in case 1 and case 3 where, all possibilities are acceptable in GCAF calculations.

Table 8. 14 Result of GCAF Jet Fire Mitigation Acceptance

GCAF Acceptance in Jet Fire			
Status	GCAF	Acceptable	Unacceptable
Case 1	5,68E+04	v	
Case 2	1,71E+06		v
Case 3	4,81E+05	v	
Case 4	9,96E+04	v	
Case 5	9,69E+04	v	
Case 6	1,24E+06		v
Case 7	1,14E+06		v

Table 8. 15 Result of GCAF VCE Mitigation Acceptance

GCAF Acceptance in VCE			
Status	GCAF	Acceptable	Unacceptable
Case 1	5,40E+05	v	
Case 2	1,60E+05	v	
Case 3	6,13E+04	v	
Case 4	1,11E+06		v
Case 5	1,06E+06		v
Case 6	6,63E+06		v
Case 7	1,14E+06		v

Table 8. 16 Result of GCAF Flash Fire Mitigation Acceptance

GCAF Acceptance in Flash Fire			
Status	GCAF	Acceptable	Unacceptable
Case 1	9,72E+05	v	
Case 2	1,22E+05	v	
Case 3	1,10E+05	v	
Case 4	8,41E+05	v	
Case 5	8,09E+05	v	

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CHAPTER IX

CONCLUSION

Based on the risk assessment that has been carried out on the potential for explosions and fires in the floating storage regasification unit (FSRU) that has been carried out, it can produce the following conclusions.

1. Hazard identification is done on the fuel supply system of BMPP 60MW using the Hazard and Operability (HAZOP) method. Deviation causes the potential for VCE, Flash Fire, Jet Fire, Gas Dispersion.
2. Frequency analysis performed using the fault tree analysis (FTA) method is performed with three leakage scenarios (10-50mm, 50-150mm and> 150mm). The frequency of leakage that has the greatest value occurs at node 4 with a leakage diameter of 10-50mm with a value of 9.48 x 10-4 per year. While the frequency of leakage that has the smallest value occurs at node 2 with a leakage diameter of 10-50mm with a value of 9.38 x 10-5 per year.
3. Frequency analysis conducted using the event tree analysis (ETA) method produces three hazardous events, namely jet fire, flash fire and gas dispersion. The probability of the biggest jet fire occurrence in node 1 scenario 10-50mm with a value of 9.48 x 10-5. Whereas the probability for the biggest flash fire event occurs in node 1 scenario 10-50mm with a value of 6.40 x 10-5. For the probability for the event of gas dispersion the greatest occurs in node 1 scenario 10-50mm with a value of 2.13 x 10-4
4. Risk Mapping using the UK Offshore FN Curve standard shows that the jet fire, Flash Fire, and VCE incidents are in ALARP conditions.
5. Mitigation in this final project is given by using LOPA with the highest efficiency is the addition of Node 3 as evidenced by the smallest GCAF calculation. The mitigation for Node 3 as the most effective as researcher recommendation were additional of safety instrument as temperature alarm of IPL frequency 1,02E-02.

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ATTACHMENT