An Application of Frank and Morgan Logical Risk Analysis on Customer Metering Systems in Jalalabad Gas Transmission and Distribution System Limited

B.Sc. ENGINEERING THESIS

SUBMITTED BY

KANIZ RUBAIYAT RICHY

Reg. No: 2018336036

Department of Petroleum and Mining Engineering

Shahjalal University of Science and Technology (SUST)

Sylhet-3114, Bangladesh.

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This thesis paper is submitted as a requirement of the partial fulfilment for the award of the degree of B.Sc. (Engg), Department of Petroleum and Mining Engineering, SUST.

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Under the Supervision of

Dr. Muhammad Farhad Howladar

Professor

Dept. of Petroleum and Mining Engineering

Shahjalal University of Science and Technology, Sylhet-3114.

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Abstract

Natural gas is the primary source of energy in Bangladesh, contributing over 70% to the country's energy needs. The exploration, production, and distribution of natural gas are vital to the economy of Bangladesh, serving industries, power generation, and residential needs.

This research employs the **Frank and Morgan Logical Risk Analysis (FMLRA)** framework, a methodical approach that combines probabilistic analysis and logical reasoning to identify, evaluate, and mitigate risks related to the gas field operations of Jalalabad Gas Transmission and Distribution System Limited, which plays a crucial role in ensuring reliable natural gas supply to the north-eastern region of Bangladesh. The study, therefore, relies on the Frank and Morgan Logical Risk Analysis framework in assessing the risk profiles of the CMSs by establishing inherent hazards, assessing the control measures, and quantifying composite risks. The study brings out marked variations in composite risk levels among the studied CMSs through tight data analysis and methodical risk modelling, therefore offering useful insights into the complex nature of risk in gas transmission and distribution operations. The clarification of particular hazards that create composite risk levels for each CMS, such as a potential fire explosion, process stability, and environmental hazard, highlights actionable insights for focused risk mitigation activities. The study's lessons are critical to developing strong risk management strategies that will maintain the safety, dependability, and sustainability of gas distribution operations as gas transmission and distribution systems change in response to shifting regulatory environments and technological breakthroughs.

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Chapter-1

Introduction

Natural gas plays a vital role in Bangladesh's energy sector, meeting over 70% of the nation's total energy demand and serving as a primary fuel for power generation, industrial operations, and domestic consumption. Beyond its production, the safe and efficient transmission of natural gas is critical to ensuring uninterrupted supply and minimizing operational hazards. Accurate measurement and proper maintenance are essential in this process, as they enable effective monitoring, loss prevention, and system integrity. The Customer Metering System (CMS) is a key component in achieving these objectives, as it ensures precise operational safety in gas distribution networks. Bangladesh's natural gas reserves are limited and play a critical role in power generation and economic stability. Efficient, accurate, and safe management of gas distribution through CMSs is essential to minimize losses, prevent hazards, and ensure sustainable energy supply for the nation. JGTDSL being one of the principal gas transmission and distribution companies in Bangladesh, serving a diverse range of residential, commercial, and industrial consumers, its strategic importance in the national energy network, ensuring the safety and reliability of its operations is crucial. The Frank and Morgan Logical Risk Analysis model provides a systematic framework for identifying, assessing, and prioritizing potential risks, thereby enabling effective management and safety assurance of the Customer Metering Systems (CMSs) within JGTDSL for accurate measurement, monitoring, and billing of gas usage as operational issues such as faulty meters, calibration errors, and insufficient maintenance can lead to inaccurate measurements, resulting in financial losses, unaccounted-for gas, and potential safety hazards.

Dos Santos, et al., (2023) applies Preliminary Hazard Analysis with the Eisenberg Vulnerability Method to assess gas distribution leak risks in China, finding poor maintenance as a major cause and estimating lethality probabilities (1%, 50%, 99%) to guide prevention. **Ismail, et al., (2018)** classifies natural gas supply risks in Malaysia into market, supply, and transportation, addressing leakage disruptions, price volatility, and dependency issues, and proposes a pipeline risk categorization model. **Ali, (2024)** conducts a QRA of City Gas Distribution networks across multiple Indian cities using PHAST-8.22, analyzing historical incidents and pipeline operations to identify hazards, estimate probabilities, and propose risk reduction measures, with emphasis on safety, reliability, and sustainability. **Hasan, et al., (2020)** assesses risks in the Jalalabad Gas Transmission and Distribution System, Bangladesh, using surveys, statistical tests, and a risk matrix, identifying hazards in workplace conditions, job stress, and safety measures, and suggesting improvements. **Sarowar & Mahmud, (2024)**

uses FMLRA to quantify CMS risks in Jalalabad Gas T&D, Bangladesh, identifying fire, process instability, and environmental hazards.

Previous monitoring practices have often been reactive rather than preventive, which increases the risk of system failures and compromises operational safety. Despite the importance of CMSs in maintaining efficiency and safety, there is a lack of systematic risk assessment tailored to these systems within JGTDSL. The Frank and Morgan Logical Risk Analysis model offers a structured approach to identifying, evaluating, and mitigating such risks. This research aims to investigate:

(a) What are the potential operational, safety, and financial risks associated with CMSs in key JGTDSL power plants?

(b) How can the Frank and Morgan Logical Risk Analysis model be applied to improve risk management, accuracy, and safety in these systems?

Although previous studies have examined certain risk aspects within JGTDSL, the growing operational demands and emerging safety concerns call for a more extensive and detailed assessment. This study therefore undertakes a broader quantitative risk evaluation of additional Customer Metering Systems (CMSs) within JGTDSL, aiming to identify hazards, quantify associated risks, and propose targeted measures to enhance operational safety and resilience.

1.1 Brief Outline of the Study Context:

Natural gas has emerged as a cornerstone of the global energy landscape, playing a pivotal role in meeting the ever-growing energy demands of industries, households, and economies worldwide. As a cleaner and more efficient alternative to transportation, manufacturing, and even chemical production, natural gas has gained prominence as a much cleaner and efficient resource than many traditional energy sources. The versatility in this respect, added to the improvement in extraction and distribution technologies, has driven the surge in demand worldwide. (Figure 1.1)

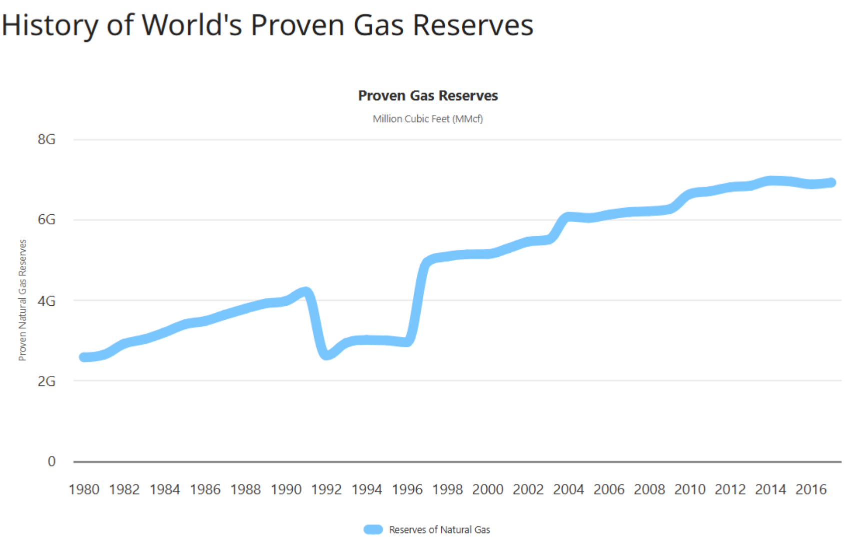

Figure 1.1: History of World's Proven Gas Reserves [2]

Experts in the global energy sector broadly agree that by 2030, global consumption (Figure 1.2) will continue to rise significantly, fueled by the expansion of industrial activities, urbanization, and the shift towards lower-carbon energy solutions. This raises critical questions: *By how much will energy demand grow, and how will this demand be fulfilled?* According to research conducted by the French Association of Oil Professionals, global energy demand is projected to double by 2030 and could potentially triple by 2050.**[1]**

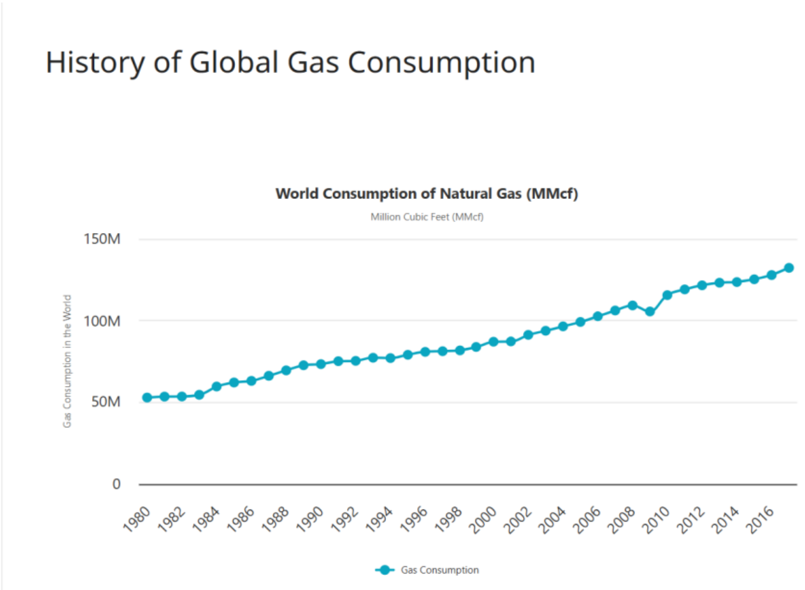

Figure 1.2: History of Global Gas Consumption (2016). **[2]**

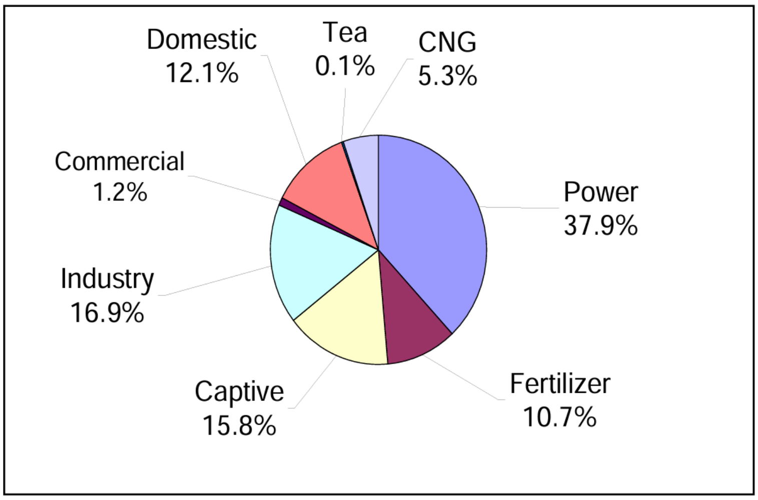

Figure 1.4: Natural Gas Consumption by Different Sectors (2009-10) **[3]**

Bangladesh is highly dependent on natural gas for its energy needs, with gas being a primary source for electricity generation, industrial use, fertilizer production, and domestic consumption. As of 2010, natural gas consumption in Bangladesh was primarily distributed across several key sectors, reflecting the diverse demand for energy resources in the country. According to the provided data, the power sector accounted for the largest share of gas consumption at 37.9%, underscoring its critical role in electricity generation. The industrial sector followed with 16.9%, while captive power generation constituted 15.8%. Fertilizer production accounted for 10.7%, and domestic use stood at 12.1%. Notably, compressed natural gas (CNG) made up 5.3%, and the tea sector accounted for a negligible 0.1%, highlighting its minimal energy requirements. Commercial usage was the smallest consumer, representing only 1.2% of the total gas consumption. (Figure 1.4)

This distribution demonstrates the significant reliance of the power and industrial sectors on natural gas, emphasizing its importance to the nation’s economy and energy security

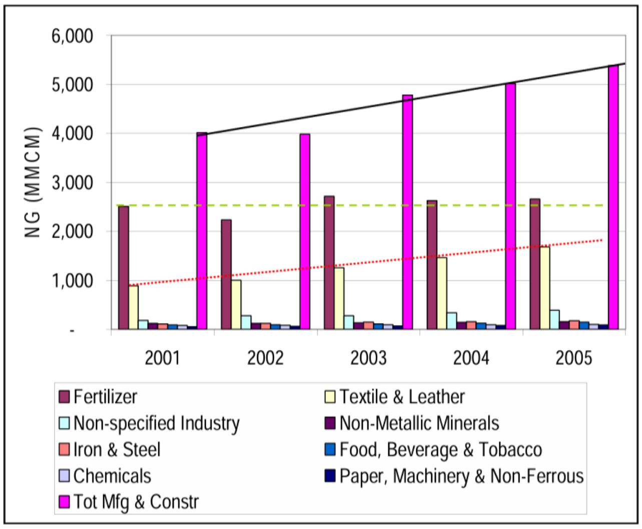

Figure 1.5: Yearly Consumption of Natural Gas by Different Industries **(2001-05)**

The industrial consumption of natural gas in Bangladesh is distributed among various sub-sectors, as depicted in the chart which reflects that total consumption of natural gas is gradually increasing day by day, which makes it very necessary to ensure efficient and safe transmission of it from the production fields to sustain economic growth. (Figure 1.5)

	Million Cubic Ft (MMcf)	**Million BOE (barrels of oil equivalent)**
Gas Reserves	**6,922,922,000**	**1,153,820**
Gas Consumption	**132,290,211**	**22,048**

Table 1.1: Summery of Global Gas Consumption till 2024. **[2]**

This increasing reliance on natural gas highlights the critical need for robust infrastructure and risk management practices to ensure its safe and efficient delivery. (Table 1.3) Within this context, Customer Metering Systems (CMS) play an integral role in the production and distribution framework, underscoring the importance of their reliability and security in the face of rising demand.

1.2 Key Concepts and Theoretical frameworks:

Risk, Safety and their assessments:

Risk and safety assessments are essential in engineering and industrial sectors to evaluate potential hazards, ensure compliance with safety standards, and implement measures to mitigate accidents. These processes are crucial in maintaining operational efficiency and safeguarding people, assets, and the environment.

1.2.1What is Safety?

Safety refers to the condition of being protected from harm or risk. It involves creating and maintaining environments, systems, or conditions that prevent injury, damage, or loss.

1.2.2 What is Risk?

According to ISO 2002, risk is defined as the combination of probability of an event and its outcome. Risk involves avoidance of loss and undesirable consequences as well as probability and estimate of potential losses.**[11]**

1.2.3 What is Risk assessment?

Risk assessment gives a better picture of various scenarios of the plant as this also includes the consequences along with the probability of occurrence of the incidents. It is also helpful in prioritizing the risk from higher to the lower. Focus can be directed toward the events with higher risk envisaged. Risk assessment includes details about severity of the accident, probability of occurrence of the accident, and its frequency.**[11]**

1.2.4 What is Quantitative Risk assessment?

A quantitative risk assessment attempts to measure the risk by relating the probability of the risk occurring to the possible severity of the outcome and then giving the risk a numerical value. This method of risk assessment is used in situations where a malfunction could be very serious. **[13]**

1.2.5 What is Hazard?

A hazard is any source of potential damage, harm, or adverse health effects on individuals, property, or the environment. It forms the basis of identifying risks during risk assessments.

1.2.6 What is Hazard Control?

Hazard control measures that already exist in the plant are identified. Additional safety measures are recommended for if the assessed risk is unacceptable or if the risk is not within the permissible limits. Information about the risk and safety measures needs to be communicated among the workers as they have the highest potential of risk that arise from foreseen hazards. Proper training needs to be imparted about the nature of hazards, their probability of occurrence, cost implications, possible controls to mitigate the consequences and their responsibilities in risk management.**[11]**

1.2.7 What is Safety Assessment?

Safety assessment involves the systematic evaluation of potential risks and hazards associated with a system, process, product, or environment to ensure its safety and reliability. It typically includes identifying hazards, assessing their likelihood and consequences, evaluating existing safety measures, and recommending or implementing risk mitigation strategies.**[15]**

1.3 Objectives:

Objectives of this study includes:

- To learn about the safety measures taken in the CMSs.
- To calculate the Hazard score and Control Score for determining the risk index.
- Calculate the composite risk in each CMS and evaluate the risks of the following CMSs.
- Ranking the CMS according to their composite risk score to evaluate which CMS has been of more risk and which CMS has been of less risk and taking necessary steps accordingly.

1.4 Area of the study:

Table:1.3 contains the list of current operational CMSs in Jalalabad Gas franchise area.

SL no	Name of CMS	CMS Capacity (MMSCFD)
01.	Shahjibazar Power Company Limited (86 MW)	25
02.	Shahjibazar 330 MW CCPP	65
03.	Shahjibazar Power Station (70 MW)	20
04.	100 MW Power Plant (Temporary CMS), Shahjibazar	15
05.	Energypac Confidence Power Venture limited (11MW)	3
06.	Summit Bibiyana-2 (341 MW)	65
07.	Bibiyana-3 Power Station- 400 MW	85
08.	Bibiyana South Power Station- 400 MW	85
09.	Barakatullah Electro Dynamics Limited (51 MW)	15
10.	Kushiara Power Company Limited (163 MW)	28
11.	Fenchuganj Power Station 90 MW Unit-1 and Unit-2	60
12.	Energy Prima Rental Power Plant (50 MW), Fenchuganj	15
13.	Desh Cambridge Kumargaon Power Company Limited (10 MW)	3
14.	Shajahanullah Power Generation Company Limited (25 MW)	7
15.	Kumargaon Power Station (20 MW)	3
16.	150 MW CCPP, Kumargaon, Sylhet	70
17.	Shahjalal Fertilizer Company Limited, Fenchuganj	70
18.	Lafarge Surma Cement Company Limited, Chattak, Sunamgnaj.	36
19.	Devpur Spur Line CMS, Khadim	80

Table 1.2: The list of current operational CMSs

Among these nineteen CMSs I've worked on six CMSs in which five are in operation and one is currently closed- Bibiyana 3 Power Plant (400 MW), Summit Bibiyana Power Plant (341 MW), Bibiyana South Combined-Cycle Power Plant, (400 MW), Shahjibazar 86 MW Gas Power Plant, Shahjibazar 70 MW (BPDB) Gas Power Plant, Shahjibazar 100 MW Gas Turbine Power Plant, BPDB(Closed).

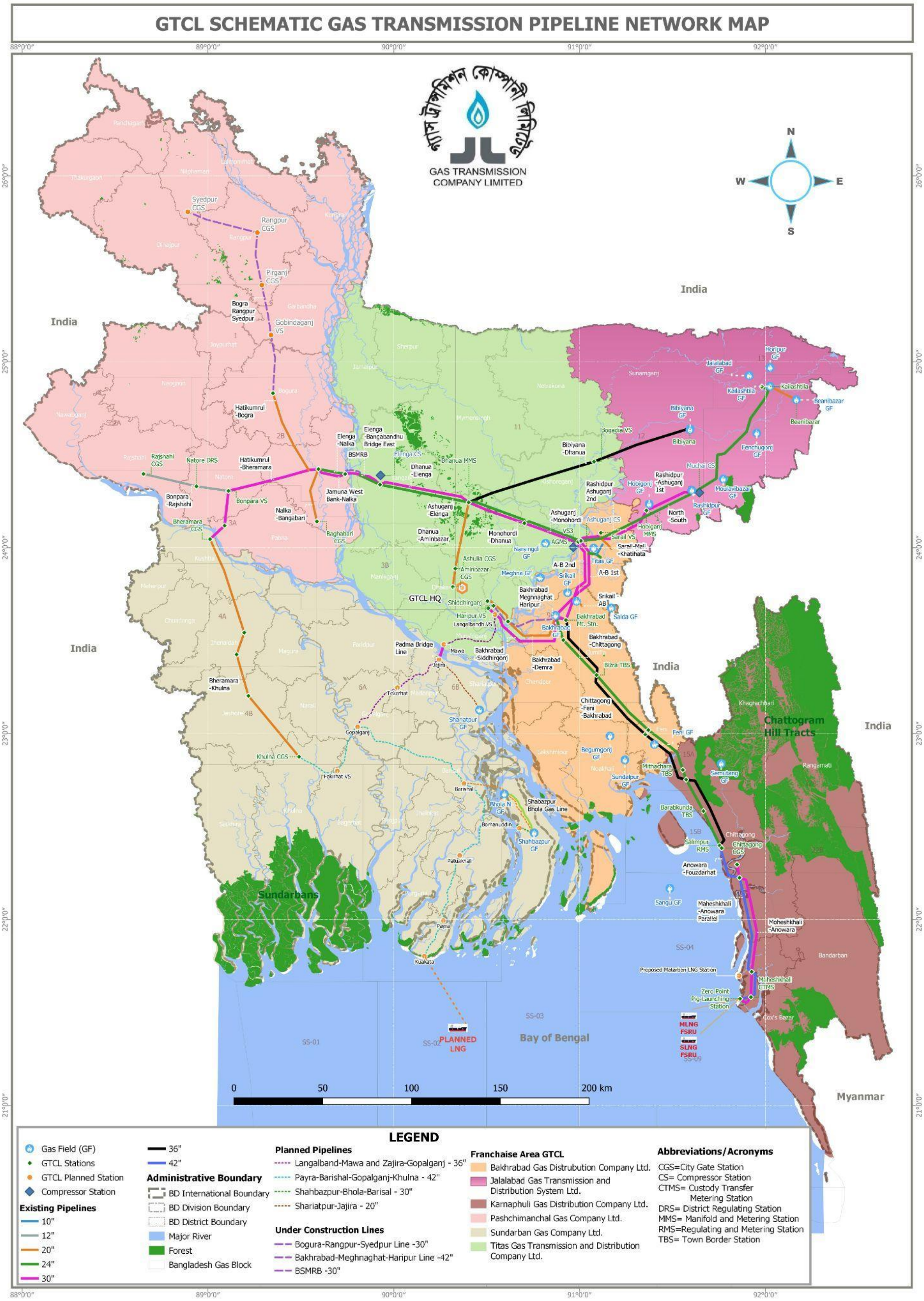

Figure 1.6: GTCL Gas transmission pipeline network in Bangladesh. **[6]**

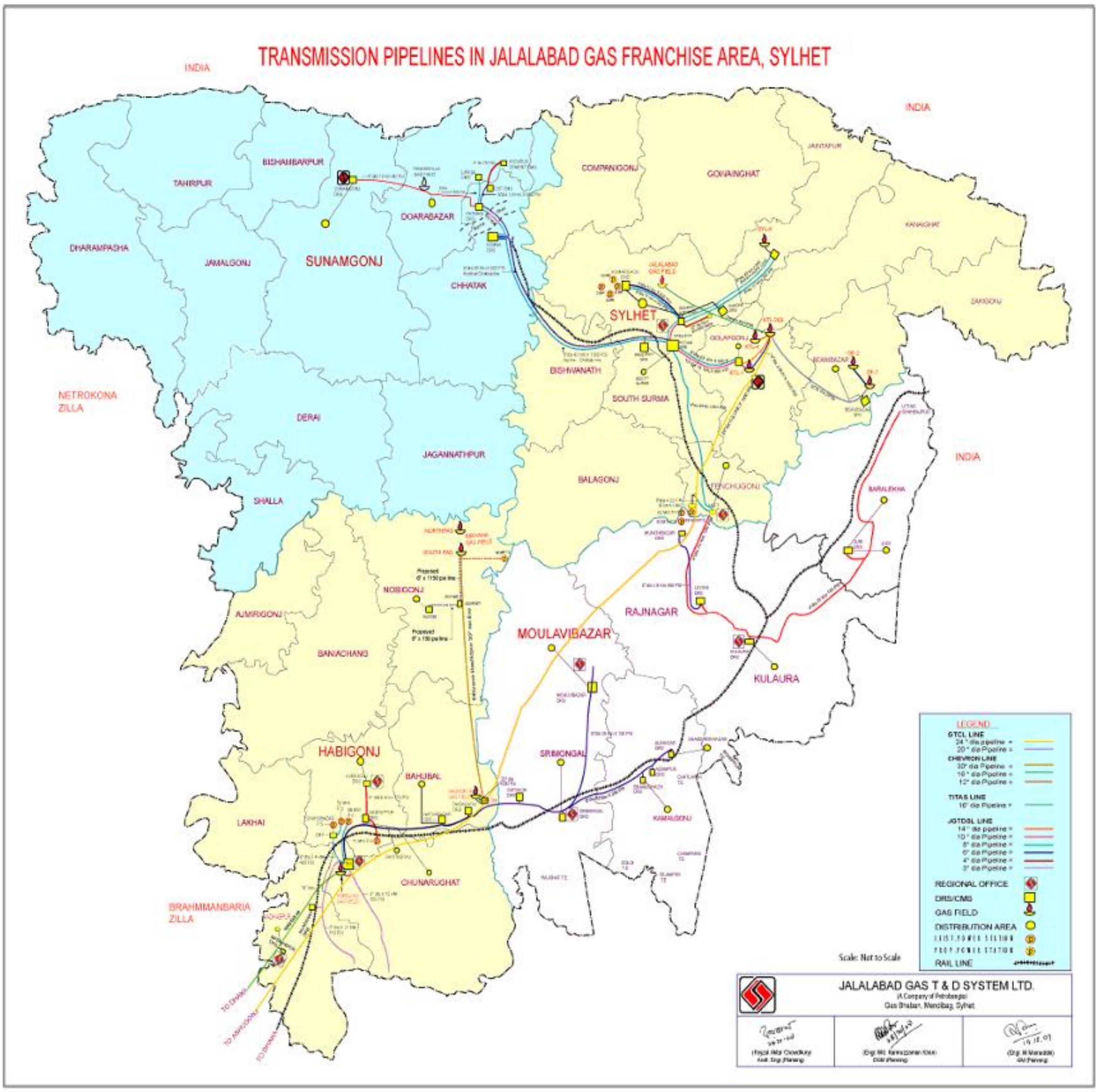

Figure 1.7: Gas transmission pipeline network of JGTDSL.**[8]**

Bibiyana-3 Power Plant (400 MW, BPDB) – The Bibiyana-3 Power Plant is situated in Parkul, Bibiyana, Nabiganj Upazila, Habiganj District, Sylhet Division, Bangladesh. It is an important national power facility, supplying 400 MW to the grid and significantly supporting Bangladesh's electricity demand through high-efficiency combined cycle technology. Its geographical position is **24° 38′ 11.6″ N, 91° 39′ 23.4″ E.** The plant receives natural gas via the Customer Metering System (CMS), transmitting approximately 13 m^3/s (about 47,200 m^3/h) at full capacity.

Summit Bibiyana Power Plant (341 MW, IPP) – The **Summit Bibiyana Power Plant** (341 MW, IPP) is located in Parkul, Nabiganj Upazila, Habiganj District, Sylhet Division. It is a key independent power producer, supplying efficient electricity to the national grid under a long-term agreement. It operates its own CMS to receive gas directly from the Bibiyana transmission line, ensuring accurate billing under its power purchase and gas supply agreements. Geographical position: **24° 38′ 22.2″ N, 91° 39′ 34.1″ E**. Gas is supplied via the CMS, transmitting about **14–16 m³/s** at full capacity.

Bibiyana South Combined-Cycle Power Plant (400 MW, BPDB) – The Bibiyana South Combined-Cycle Power Plant (400 MW, BPDB) is located in Parkul, Nabiganj, Habiganj District, Sylhet Division. It plays a key role in supplying efficient grid power for Bangladesh. Coordinates: **24° 38′ 6″ N, 91° 39′ 38″ E**. Gas is supplied via the CMS from the Bibiyana gas field, transmitting about **520–694 m³/s** at peak load, it's has a CMS designed to handle large, steady combined-cycle loads, with high-accuracy turbine meters and automated pressure control.

Shahjibazar 86 MW Gas Power Plant – The **Shahjibazar 86 MW Gas Power Plant** is located in Fatehpur, Madhabpur Upazila, Habiganj District, Sylhet Division. Operated by Shahjibazar Power Co. Ltd. under a BOO agreement since 2009, it supplies 86 MW to the national grid. Positioned at **24° 15′ 19″ N, 91° 22′ 37″ E**, the plant runs on natural gas supplied via the Jalalabad Gas CMS, using 32 JGS 620 gas engine units for generation.

Shahjibazar 70 MW (BPDB) – The **Shahjibazar 70 MW Gas Power Plant (BPDB)** is located in Shahjibazar, Madhabpur Upazila, Habiganj District, Sylhet Division, at **24° 15′ 19″ N, 91° 22′ 37″ E**. This state-owned gas turbine plant, commissioned in 1968, is supplied with natural gas via the Customer Metering System (CMS) and has been a reliable source of electricity for the national grid. It uses a CMS calibrated for peaking operation, measuring fluctuating daily flows.

Shahjibazar 100 MW Gas Turbine (BPDB) – The **Shahjibazar 100 MW Gas Turbine Power Plant (BPDB)** is located in Shahjibazar, Habiganj District, Sylhet Division, at approximately **24° 15′ 19″ N, 91° 22′ 37″ E**. Supplied with natural gas via the CMS from the Habiganj Gas Field, it was commissioned in 2016 with an LMS100 turbine and is currently offline due to turbine malfunction.

Figure 1.8: Bibiyana-3 Power Station- 400 MW

Figure 1.9: Bibiyana South Power Station- 400 MW

Figure 1.10: Summit Bibiyana-2 (341 MW)

Figure 1.11: Site visiting for data collection.

Figure 1.12: Summit Bibiyana-2 (341 MW)

Figure 1.13: Shahjibazar Power Company Limited (86 MW)

Figure 1.14: Shahjibazar Power Station (70 MW) Site visiting.

Figure: 1.15: 100 MW Power Plant (Temporary CMS), Shahjibazar.

1.5 Significance of the study:

The significance of this study is that it may potentially improve the safety, reliability, and efficiency of Customer Metering Systems (CMS) in natural gas distribution, which play a crucial role in accurately measuring gas consumption and preventing system failures. In Bangladesh, natural gas being the main energy source, the demand is also increasing, making it essential to protect the infrastructure that supports gas distribution.

The application of Quantitative Risk Assessment (QRA) by Frank and Morgan's FMLRA, is a new approach to identify, evaluate, and mitigate risks in CMS. The probabilistic nature of this method allows a structured and analytical approach toward safety, which allows decision-makers to prioritize interventions based on the likelihood of failure and potential impact. Through a structured QRA model, the utilities can reduce the chances of safety incidents, have more accurate billing, and avoid operational disruptions. Thus, gas utilities will help the sustainable growth of energy industries.

[https://www.sra.org/]

Chapter-2

Literature Review

2.1 Literature Review

Gas distribution and transmission systems play a crucial role in the energy sector, ensuring the safe and efficient delivery of natural gas to customers across commercial, industrial, and residential sectors. These systems consist of a complex network of pipelines, compressor stations, and metering facilities.**[16]** Effective risk management is essential to maintain the integrity and reliability of natural gas systems. The infrastructure is classified into three categories:

1. **Gathering Systems**: Pipelines transporting raw natural gas from production sites to processing plants.

2. **Transmission Systems**: High-pressure pipelines designed for large-scale, long-distance transportation of gas.

3. **Distribution Systems**: The final delivery stage, where gas is distributed to end-users at reduced pressure.**[20]**

Each of them differs in diameter and internal pressure. Transmission pipelines are large, high-pressure pipelines that transport natural gas over long distances across the country, delivering it to processing or storage facilities. Gathering pipelines collect raw natural gas directly from production wells. The distribution system, as the final stage of the transportation process, delivers natural gas at lower pressures to end users. **[20]** The Customer Metering System (CMS) is a crucial component of gas distribution networks, designed to accurately measure and record the gas consumption of end users. **[18]** These systems are vulnerable to a variety of risks, including breakdowns in equipment, and human errors, which can result in incorrect invoicing, revenue loss, and significant safety issues.**[20]** Risk assessment methodologies are essential tools employed across numerous industries, including the energy sector, to systematically identify, evaluate, and address potential risks that could impact operations, safety, or performance. Over the years, various techniques have been developed to cater to diverse needs and scenarios. Among these, methods like Failure Mode and Effects Analysis (FMEA) have gained significant recognition for their ability to analyze potential failure points and their consequences, helping organizations implement proactive measures to mitigate risks effectively. **[19]** The discussion on several risk assessment approaches used in the energy industry, including Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), and Event Tree Analysis (ETA). It also introduces the Frank and Morgan Logical Risk Analysis.**[11]** A key component of risk management is logical risk analysis, which offers a methodical framework for locating, evaluating, and reducing hazards in complex systems. Many theories, approaches, and frameworks have been developed over time to address the difficulties in identifying and controlling risks. The Frank and Morgan Logical Risk Analysis model is a noteworthy methodology in this field that provides a methodical approach to risk analysis through probabilistic evaluations and logical reasoning.

Frank and Morgan's Logical Risk Analysis model offers a comprehensive approach to risk evaluation through probabilistic analysis and logical reasoning. In their work, *Logical Risk Analysis for Occupational Safety and Health*, Frank and Morgan outline a systematic process for identifying risks, assessing their likelihood and impact, and implementing effective risk mitigation strategies.**[21]**

2.2 Challenges and Limitations

Logical risk analysis, while offering valuable insights, faces several limitations. A primary obstacle is the inherent ambiguity surrounding risk assessment, particularly in complex systems. These systems often exhibit high levels of unpredictability and fluctuation, making precise risk estimation challenging.

Moreover, the effectiveness of logical risk analysis heavily relies on the quality and accuracy of the data used. Obtaining reliable data in real-world scenarios can be a significant hurdle, potentially hindering the analysis's overall accuracy and applicability.

Chaper-3

Methodology

3.1 Flowchart of Methodology:

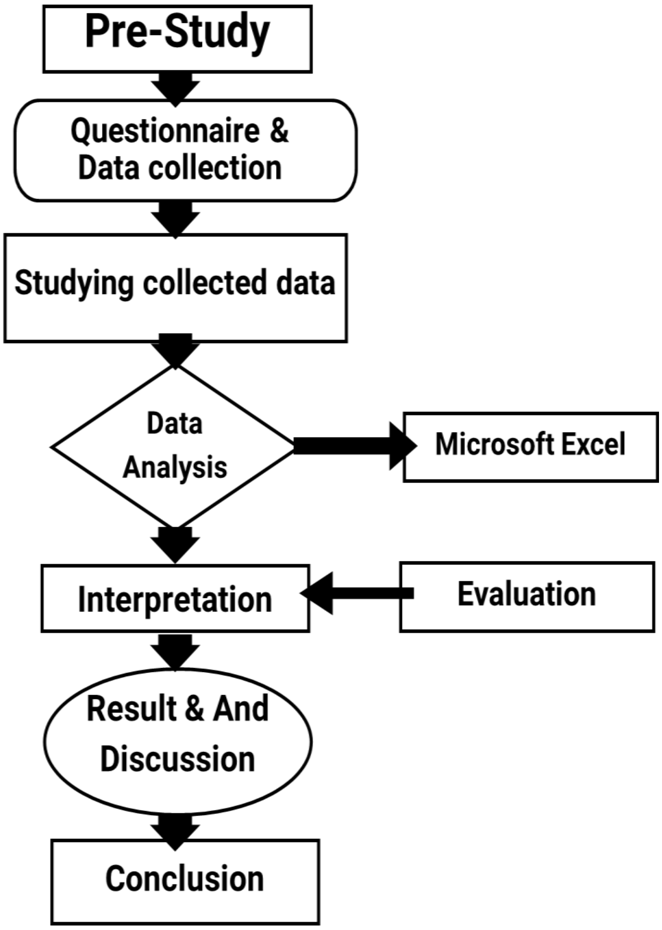

Figure:3.1 Flowchart of Methodology.

3.2 Frank and Morgan Logical Risk Analysis Model:

Frank and Morgan (1979) proposed a systematic method of financing risk and presented a scheme for risk reduction. Their model is applicable to any process industries and therefore valid for oil and gas industries as well. Suitable CMSs were selected for applying this method for targeting risk reduction. This method involves six steps of risk analysis, which are as follows:

Step 1: Compute risk index for each department

Each CMS unit inherently has a risk level, which is to be identified first. This can be done by evaluating the hazards present and the control measures available. This is also called as the first level of risk assessment. It is generally done by preparing a checklist, shown in Table:4. Control scores and hazard scores for all the departments are established from the checklist given in Table:5.

Hazard checklist has six groups of hazards. There are scores associated with each hazard, within each group. These scores are summed up for hazards applied within that group. The hazard score for a group is given by:

Hazard score = sum × hazard weightage

Hazard score for each CMS unit is the sum of the scores computed for each of the six groups. Similarly, one can estimate the control scores as well. Control score for each CMS unit is the sum of the scores of each of the six groups as tabulated. Control score for a group is given by:

Control score = sum × control measure weightage

After determining the hazard and control scores for each CMS unit, risk index can be calculated as given below. Risk index may be either positive or negative depending upon the control measures and hazard groups present in each unit.

Risk index = control score - hazard score

Step 2: Determine relative risk for each CMS unit

The aim is to rank the CMS units. This is due to the fact that the unit with the highest risk index (highest positive value) is not likely to need much reduction in hazards. High risk index means that the controls are very effective. Those units will need funds lesser than other department to eliminate hazards. In fact, use the best unit risk score as the base reference. All curves are normalized with respect to the best unit. This is done by subtracting the risk score of the best unit from risk scores of the concerned unit. This adjustment will make the relative risk of best unit as zero.

Step 3: Compute percentage risk index for each CMS unit

This indicates relative contribution of each unit to the total risk of the network. Relative risk of each unit is converted to a percent of total risk by a simple procedure. Total risk of all unit is the sum of absolute value of relative risk of each unit. The percent risk index is given by:

$$\%\text{ Risk index} = \frac{\text{relative risk}}{\sum_0^i \text{relative risk}} \times 100\%$$

Step 4: Determine composite exposure dollars for each CMS unit

The estimated risk is subsequently converted to financial value now. This estimates the financial value of risk for each unit. Composite exposure dollars are the sum of monetary value of three components:

(i) property value

(ii) business interruption and

(iii) personnel exposure.

Property value is estimated by the replacement cost of all materials and equipment at risk in the CMS. Business interruption is computed as the product of unit cost of goods and production per year and expected percentage capacity. Personnel exposure is the product of total number of people in the department during the most populated shift and the monetary value of each person.

Step 5: Compute composite risk for each CMS unit

For each unit, composite risk is the product of composite exposure dollars and percentage risk index of that unit. This value represents the relative risk of each unit. Monetary units for composite risk are in Dollars. Composite risk for each unit is given by:

Composite risk = (composite exposure) × (%risk index)

Step 6: Risk ranking

This is the final step in the process. Risk ranking of the CMS units is done based on the composite risk as this will help the risk managers to decide the requirement of fund for each unit either to mitigate risk or at least to control risk. The CMS units are ranked from highest composite score to the lowest.

[10]

3.3 Checklist Contents

This study is focused on the risk and safety assessment of natural gas transmission and distribution systems. A comprehensive checklist has been developed to evaluate key aspects of these systems, which is presented in Table 1 and Table 2 for further analysis.

Table 2.1: Hazard groups and hazard score

Hazard Group	Group hazard factor	Hazard	Rating points
Fire/explosion potential	10	Large inventory of flammables	**2**
		Flammables generally distributed in the department rather than localized	**2**
		Flammables normally in vapor phase rather than liquid phase	**2**
		Systems opened routinely, allowing flammable/air mix, versus a totally closed system	**2**
		Flammables having low flash points and high sensitivities	**1**
		Flammables heated and processed above flash point	**1**
Complexity of process	8	Need for precise reactant addition and control	**2**
		Considerable instrumentation requiring special operator understanding	**2**
		Troubleshooting by supervisor rather than operator	**2**
		Large number of operations and/or equipment monitored by one operator	**1**
		Complex layout of equipment and many control stations	**1**
		Difficult to startup or shutdown operations	**1**
		Many critical operations to be maintained	**1**
Stability of process	7	Severity of uncontrolled situation	**3**
		Materials that are sensitive to air, shock, heat, water, or other natural contaminants in the process	**2**
		Potential exists for uncontrolled reactions	**2**
		Raw materials and finished goods that require special storage attention	**1**
		Intermediates that are thermally unstable	**1**

		Obnoxious gases present or stored under pressure	**1**
Operating pressure involved	6	Process pressure in excess of 110lb/in^2(gauge)	**3**
		Process pressure above atmosphere but less than 110lb/in^2 (gauge)	**2**
		Process pressure ranges from vacuum to atmospheric	**1**
		Pressures are process rather than utility related	**3**
		High pressure situations are in operator	**2**
		Excessive sight glass application	**1**
		Nonmetallic materials of construction in pressure service	**1**
Personnel/environment hazard potential	4	Exposure to process materials pose high potential for severe burn or severe health risks	**3**
		Process materials corrosive to equipment	**2**
		Potential for excursion above Threshold Limit Value (TLV)	**2**
		Spills and/or flumes have high impact on equipment, people, or services	**1**
		High noise levels make communication difficult	**1**
High temperatures	2	Equipment temperatures exist in <100°C range (low)	**1**
		Equipment temperatures exists in 100<170°C range	**2**
		Equipment temperatures exists in 170<230°C range	**3**
		High temperature situations are m operator-frequented area	**2**
		Overflows and/or leaks are fairly common	**2**
		Heat Stress Possibilities from nature of work or ambient air.	**2**

Table 2.2: Control scores and control group

Control Group	Control Group Factor	Control	Rating points
Fire protection	10	Automatic sprinkler system capable of meeting demands	**4**
		Supervisors and operators knowledgeable in installed fire protection systems are trained properly response to fire	**2**
		Adequate distribution of fire extinguishers	**1**
		Fire protection system inspected and tested with regular frequency	**1**
		Building and equipment provided with capability to isolate and control fire	**1**
		Special fire detection and protection provided where indicated	**1**
Electrical integrity	8	Electrical equipment installed to meet National Electrical Code area classification	**3**
		Electrical switches labeled to identify equipment served	**1**
		Integrity of installed electrical equipment maintained	**1**
		Class I, division 2 installations provided with sealed devices Explosion proof equipment provided or purged reliably and good electrical isolation between hazardous and non hazardous areas	**1**
		All electrical equipment capable of being locked out	**1**
		Disconnects provided, identified, inspected, and tested regularly	**1**
		Lighting securely installed and facilities properly grounded	**1**
Safety devices	7	Relief devices provided and relieving is to a safe area	**3**
		Confidence that interlocks and alarms are operable	**2**
		Operating instructions are complete and current, and department has continued training and/or retaining program	**2**
		Safety devices are properly selected to match application	**1**

		Critical safety devices identified and included in regular testing program	**1**
		Fail safe instrumentation provided	**1**
Inerting and dip piping	5	Vessels handling flammables provided with dip pipes	**2**
		Vessels handling flammables provided with reliable inerting system	**2**
		Effectiveness of inerting assured by regular inspection and testing	**2**
		Inerting instruction provided and understood	**1**
		Inerting system designed to cover routine and emergency startup	**1**
		Equipment ground visible and tested regularly	**1**
		Friction hot spots identified and monitored	**1**
Ventilation/Open construction	4	No flammables exist or open air construction is provided	**3**
		Local ventilation provided to prevent unsafe levels of flammable, toxic, or obnoxious vapors	**2**
		Provision made for containing and controlling large spills and leaks of hazardous materials	**2**
		Building design provides for natural ventilation to prevent accumulation of dangerous vapors	**1**
		Sumps, pits, etc., nonexistent or else properly ventilated or monitored	**1**
		Equipment entry prohibited until safe atmosphere assured	**1**
Accessibility and/or separation	2	Critical shutdown devices and/or switches visible and accessible	**2**
		Adjacent operations or services protected from exposure resulting from incident in concerned facility	**2**
		Operating personnel protected from hazards by location	**2**
		Orderly spacing of equipment and materials within the concerned facility	**1**
		Adjacent operations offer no hazard or exposure	**1**
		Hazardous operations within the facility well isolated	**1**

Chaper-4

Result

4.1 Checklist:

Table:4.1: Hazard Score Measure of Bibiyana 3 (400 MW) Power Plant

Hazard Group	**Hazard**	**Finding**	**Rating points**	**Sum of rating points**	**Hazard Group Factor**	**Score**
	Large inventory of flammables	**Y**	**2**	**8**	**10**	**80**
	Flammables generally distributed in the department rather than localized	**Y**	**2**			
	Flammables normally in vapor phase rather than liquid phase	**Y**	**2**			
	Systems opened routinely, allowing flammable/air mix, versus a totally closed system	**N**	**0**			
	Flammables having low flash points and high sensitivities	**Y**	**1**			
	Flammables heated and processed above flash point	**Y**	**1**			
7Complexity of process	Need for precise reactant addition and control	**N**	**0**	**6**	**8**	**48**
	Considerable instrumentation requiring special operator understanding	**Y**	**2**			
	Troubleshooting by supervisor rather than operator	**Y**	**2**			
	Large number of operations and/or equipment monitored by one operator	**N**	**0**			

	Complex layout of equipment and many control stations	**Y**	**1**			
	Difficult to start up or shut down operations	**N**	**06**			
	Many critical operations to be maintained	**Y**	**1**			
Stability of process	Severity of uncontrolled situation	**Y**	**3**	**6**	**7**	**42**
	Materials that are sensitive to air, shock, heat, water, or other natural contaminants in the process	**Y**	**2**			
	Potential exists for uncontrolled reactions	**N**	**0**			
	Raw materials and finished goods that require special storage attention	**Y**	**1**			
	Intermediates that are thermally unstable	**N**	**0**			
	Obnoxious gases present or stored under pressure	**N**	**0**			
Operating pressure involved	Process pressure in excess of 110lb/in2 (gauge)	**Y**	**3**	**10**	**6**	**60**
	Process pressure above atmosphere but less than 110lb/in2 (gauge)	**Y**	**2**			
	Process pressure ranges from vacuum to atmospheric	**N**	**0**			

	Pressures are process rather than utility related	**Y**	**3**			
	High pressure situations are in operator	**Y**	**2**			
	Excessive sight glass application	**N**	**0**			
	Non-metallic materials of construction in pressure service	**N**	**0**			
Personnel/ environment hazard potential	Exposure to process materials pose high potential for severe burn or severe health risks	**N**	**0**	**3**	**4**	**12**
	Process materials corrosive to equipment	**Y**	**2**			
	Potential for excursion above Threshold Limit Value (TLV)	**N**	**0**			
	Spills and/or flumes have high impact on equipment, people, or services	**Y**	**1**			
	High noise levels make communication difficult	**N**	**0**			
High temperatures	Equipment temperatures exist in	**Y**	**1**	**3**	**2**	**6**
	Equipment temperatures exists in 100<170°C range	**N**	**0**			
	Equipment temperatures exists in 170<230°C range	**N**	**0**			
	High temperature situations are m operator-frequented area	**N**	**0**			

	Overflows and/or leaks are fairly common	**N**	**0**			
	Heat Stress Possibilities from nature of work or ambient air	**N**	**0**			

Table:4.2: Hazard Score of Bibiyana 3 (400 MW) Power Plant

Hazard Score
248

Table:4.3: Control Score Measure of Bibiyana 3 (400 MW) Power Plant

Control Group	Control	Founding	Rating Points	Sum of rating points	Control Group Factor	Score
Fire protection	Automatic sprinkler system capable of meeting demands	**N**	**0**	**6**	**10**	**60**
	Supervisors and operators knowledgeable in installed fire protection systems are trained properly response to fire	**Y**	**2**			
	Adequate distribution of fire extinguishers	**Y**	**1**			
	Fire protection system inspected and tested with regular frequency	**Y**	**1**			
	Building and equipment provided with capability to isolate and control fire	**Y**	**1**			

	Special fire detection and protection provided where indicated	**Y**	**1**			
Electrical integrity	Electrical equipment installed to meet National Electrical Code area classification	**Y**	**3**	**9**	**8**	**72**
	Electrical switches labeled to identify equipment served	**Y**	**1**			
	Integrity of installed electrical equipment maintained	**Y**	**1**			
	Class I, division 2 installations provided with sealed devices Explosion proof equipment provided or purged reliably and good electrical isolation between hazardous and non-hazardous areas	**Y**	**1**			
	All electrical equipment capable of being locked out	**Y**	**1**			
	Disconnects provided, identified, inspected, and tested regularly	**Y**	**1**			
	Lighting securely installed and facilities properly grounded	**Y**	**1**			
Safety devices	Relief devices provided and relieving is to a safe area	**Y**	**3**	**8**	**7**	**56**
	Confidence that interlocks and alarms are operable	**Y**	**2**			
	Operating instructions are complete and current, and department has continued training and/or retaining program	**Y**	**2**			

	Safety devices are properly selected to match application	**Y**	**1**			
	Critical safety devices identified and included in regular testing program	**Y**	**1**			
	Fail safe instrumentation provided	**Y**	**1**			
Inerting and dip piping	Vessels handling flammables provided with dip pipes	**Y**	**2**	**10**	**5**	**50**
	Vessels handling flammables provided with reliable inerting system	**Y**	**2**			
	Effectiveness of inerting assured by regular inspection and testing	**Y**	**2**			
	Inerting instruction provided and understood	**Y**	**1**			
	Inerting system designed to cover routine and emergency startup	**Y**	**1**			
	Equipment ground visible and tested regularly	**Y**	**1**			
	Friction hot spots identified and monitored	**Y**	**1**			
Ventilation/Open construction	No flammables exist or open air construction is provided	**Y**	**3**	**10**	**4**	**40**
	Local ventilation provided to prevent unsafe levels of flammable, toxic, or obnoxious vapors	**Y**	**2**			

	Provision made for containing and controlling large spills and leaks of hazardous materials	**Y**	**2**			
	Building design provides for natural ventilation to prevent accumulation of dangerous vapors	**Y**	**1**			
	Sumps, pits, etc., nonexistent or else properly ventilated or monitored	**Y**	**1**			
	Equipment entry prohibited until safe atmosphere assured	**Y**	**1**			
Accessibility and/or separation	Critical shutdown devices and/or switches visible and accessible	**Y**	**2**	**9**	**2**	**18**
	Adjacent operations or services protected from exposure resulting from incident in concerned facility	**Y**	**2**			
	Operating personnel protected from hazards by location	**Y**	**2**			
	Orderly spacing of equipment and materials within the concerned facility	**Y**	**1**			
	Adjacent operations offer no hazard or exposure	**Y**	**1**			
	Hazardous operations within the facility well isolated	**Y**	**1**			

Table 4.4: Control Score of Bibiyana 3 (400 MW) Power Plant

Control Score
296

Table:4.5: Hazard Score Measure of Summit Bibiyana (341 MW)

Hazard Group	Hazard	Finding	Rating points	Sum of rating points	Hazard Group Factor	Score
	Large inventory of flammables	**Y**	**2**	**8**	**10**	**80**
	Flammables generally distributed in the department rather than localized	**Y**	**2**			
	Flammables normally in vapor phase rather than liquid phase	**Y**	**2**			
	Systems opened routinely, allowing flammable/air mix, versus a totally closed system	**N**	**0**			
	Flammables having low flash points and high sensitivities	**Y**	**1**			
	Flammables heated and processed above flash point	**Y**	**1**			
Complexity of process	Need for precise reactant addition and control	**N**	**0**	**7**	**8**	**56**
	Considerable instrumentation requiring special operator understanding	**Y**	**2**			

	Troubleshooting by supervisor rather than operator	**Y**	**2**			
	Large number of operations and/or equipment monitored by one operator	**Y**	**1**			
	Complex layout of equipment and many control stations	**Y**	**1**			
	Difficult to startup or shutdown operations	**N**	**0**			
	Many critical operations to be maintained	**Y**	**1**			
Stability of process	Severity of uncontrolled situation	**Y**	**3**	**7**	**7**	**49**
	Materials that are sensitive to air, shock, heat, water, or other natural contaminants in the process	**Y**	**2**			
	Potential exists for uncontrolled reactions	**N**	**0**			
	Raw materials and finished goods that require special storage attention	**Y**	**2**			
	Intermediates that are thermally unstable	**N**	**0**			
	Obnoxious gases present or stored under pressure	**N**	**0**			
	Process pressure in excess of 110lb/in2 (gauge)	**Y**	**3**	**8**	**6**	**48**

Operating pressure involved	Process pressure above atmosphere but less than 110lb/in2 (gauge)	**N**	**0**			
	Process pressure ranges from vacuum to atmospheric	**N**	**0**			
	Pressures are process rather than utility related	**Y**	**3**			
	High pressure situations are in operator	**Y**	**2**			
	Excessive sight glass application	**N**	**0**			
	Non-metallic materials of construction in pressure service	**N**	**0**			
4Personnel/ environment hazard potential	Exposure to process materials pose high potential for severe burn or severe health risks	**N**	**0**	**1**	**4**	**4**
	Process materials corrosive to equipment	**N**	**0**			
	Potential for excursion above Threshold Limit Value (TLV)	**N**	**0**			
	Spills and/or flumes have high impact on equipment, people, or services	**Y**	**1**			
	High noise levels make communication difficult	**N**	**0**			
High temperatures	Equipment temperatures exist in	**Y**	**1**	**1**	**2**	**2**
	Equipment temperatures exists in 100<170°C range	**N**	**0**			

	Equipment temperatures exists in 170<230°C range	**N**	**0**			
	High temperature situations are m operator-frequented area	**N**	**0**			
	Overflows and/or leaks are fairly common	**N**	**0**			
	Heat Stress Possibilities from nature of work or ambient air	**N**	**0**			

Table:4.6: Hazard Score of Summit Bibiyana (341 MW)

Hazard Score
239

Table:4.7: Control Score Measure of Summit Bibiyana (341 MW)

Control Group	Control	Founding	Rating Points	Sum of rating points	Control Group Factor	Score
Fire protection	Automatic sprinkler system capable of meeting demands	**Y**	**2**	**6**	**10**	**60**
	Supervisors and operators knowledgeable in installed fire protection systems are trained properly response to fire	**Y**	**2**			
	Adequate distribution of fire extinguishers	**Y**	**2**			
	Fire protection system inspected and tested with regular frequency	**N**	**0**			

	Building and equipment provided with capability to isolate and control fire	**Y**	**1**			
	Special fire detection and protection provided where indicated	**Y**	**1**			
Electrical integrity	Electrical equipment installed to meet National Electrical Code area classification	**N**	**0**	**9**	**8**	**72**
	Electrical switches labeled to identify equipment served	**Y**	**2**			
	Integrity of installed electrical equipment maintained	**Y**	**2**			
	Class I, division 2 installations provided with sealed devices Explosion proof equipment provided or purged reliably and good electrical isolation between hazardous and non hazardous areas	**N**	**0**			
	All electrical equipment capable of being locked out	**Y**	**1**			
	Disconnects provided, identified, inspected, and tested regularly	**N**	**0**			
	Lighting securely installed and facilities properly grounded	**Y**	**1**			
Safety devices	Relief devices provided and relieving is to a safe area	**Y**	**3**	**10**	**7**	**70**
	Confidence that interlocks and alarms are operable	**Y**	**2**			

	Operating instructions are complete and current, and department has continued training and/or retaining program	**Y**	**2**			
	Safety devices are properly selected to match application	**Y**	**1**			
	Critical safety devices identified and included in regular testing program	**Y**	**1**			
	Fail safe instrumentation provided	**Y**	**1**			
Inerting and dip piping	Vessels handling flammables provided with dip pipes	**Y**	**2**	**10**	**5**	**50**
	Vessels handling flammables provided with reliable inerting system	**Y**	**2**			
	Effectiveness of inerting assured by regular inspection and testing	**Y**	**2**			
	Inerting instruction provided and understood	**Y**	**1**			
	Inerting system designed to cover routine and emergency startup	**Y**	**1**			
	Equipment ground visible and tested regularly	**Y**	**1**			
	Friction hot spots identified and monitored	**Y**	**1**			
	No flammables exist or open air construction is provided	**Y**	**3**	**10**	**4**	**40**

Ventilation/Open construction	Local ventilation provided to prevent unsafe levels of flammable, toxic, or obnoxious vapors	**Y**	**2**			
	Provision made for containing and controlling large spills and leaks of hazardous materials	**Y**	**2**			
	Building design provides for natural ventilation to prevent accumulation of dangerous vapors	**Y**	**1**			
	Sumps, pits, etc., non existent or else properly ventilated or monitored	**Y**	**1**			
	Equipment entry prohibited until safe atmosphere assured	**Y**	**1**			
Accessibility and/or separation	Critical shutdown devices and/or switches visible and accessible	**Y**	**2**	**9**	**2**	**18**
	Adjacent operations or services protected from exposure resulting from incident in concerned facility	**Y**	**2**			
	Operating personnel protected from hazards by location	**Y**	**2**			
	Orderly spacing of equipment and materials within the concerned facility	**Y**	**1**			
	Adjacent operations offer no hazard or exposure	**Y**	**1**			
	Hazardous operations within the facility well isolated	**Y**	**1**			

Table:4.8: Control Score of Summit Bibiyana (341 MW)

Control Score
310

Table:4.9: Hazard Score Measure of Bibiyana South (400 MW)

Hazard Group	Hazard	Finding	Rating points	Sum of rating points	Hazard Group Factor	Score
Fire/explosion potential	Large inventory of flammables	**Y**	**2**	**8**	**10**	**80**
	Flammables generally distributed in the department rather than localized	**Y**	**2**			
	Flammables normally in vapor phase rather than liquid phase	**Y**	**2**			
	Systems opened routinely, allowing flammable/air mix, versus a totally closed system	**N**	**0**			
	Flammables having low flash points and high sensitivities	**Y**	**2**			
	Flammables heated and processed above flash point	**Y**	**1**			
Complexity of process	Need for precise reactant addition and control	**N**	**0**	**6**	**8**	**48**

	Considerable instrumentation requiring special operator understanding	**Y**	**2**			
	Troubleshooting by supervisor rather than operator	**Y**	**2**			
	Large number of operations and/or equipment monitored by one operator	**Y**	**1**			
	Complex layout of equipment and many control stations	**Y**	**1**			
	Difficult to startup or shutdown operations	**N**	**0**			
	Many critical operations to be maintained	**Y**	**1**			
Stability of process	Severity of uncontrolled situation	**Y**	**3**	**6**	**7**	**42**
	Materials that are sensitive to air, shock, heat, water, or other natural contaminants in the process	**Y**	**2**			
	Potential exists for uncontrolled reactions	**N**	**0**			
	Raw materials and finished goods that require special storage attention	**Y**	**1**			
	Intermediates that are thermally unstable	**N**	**0**			
	Obnoxious gases present or stored under pressure	**N**	**0**			

Operating pressure involved	Process pressure in excess of 110lb/in2 (gauge)	**Y**	**3**	**10**	**6**	**60**
	Process pressure above atmosphere but less than 110lb/in2 (gauge)	**Y**	**2**			
	Process pressure ranges from vacuum to atmospheric	**N**	**0**			
	Pressures are process rather than utility related	**Y**	**3**			
	High pressure situations are in operator	**Y**	**2**			
	Excessive sight glass application	**N**	**0**			
	Non-metallic materials of construction in pressure service	**N**	**0**			
Personnel/ environment hazard potential	Exposure to process materials pose high potential for severe burn or severe health risks	**N**	**0**	**3**	**4**	**12**
	Process materials corrosive to equipment	**N**	**0**			
	Potential for excursion above Threshold Limit Value (TLV)	**N**	**0**			
	Spills and/or flumes have high impact on equipment, people, or services	**Y**	**1**			
	High noise levels make communication difficult	**Y**	**1**			

High temperatures	Equipment temperatures exist in	**Y**	**1**	**3**	**2**	**6**
	Equipment temperatures exists in 100<170°C range	**N**	**0**			
	Equipment temperatures exists in 170<230°C range	**N**	**0**			
	High temperature situations are m operator-frequented area	**Y**	**2**			
	Overflows and/or leaks are fairly common	**N**	**0**			
	Heat Stress Possibilities from nature of work or ambient air	**N**	**0**			

Table:4.10: Hazard Score of Bibiyana South (400 MW)

Hazard Score
248

Table:4.11: Control Score Measure of Bibiyana South (400 MW)

Control Group	Control	Finding	Rating Points	Sum of rating points	Control Group Factor	Score
Fire protection	Automatic sprinkler system capable of meeting demands	**N**	**0**	**6**	**10**	**60**

	Supervisors and operators knowledgeable in installed fire protection systems are trained properly response to fire	**Y**	**2**			
	Adequate distribution of fire extinguishers	**Y**	**1**			
	Fire protection system inspected and tested with regular frequency	**Y**	**1**			
	Building and equipment provided with capability to isolate and control fire	**Y**	**1**			
	Special fire detection and protection provided where indicated	**Y**	**1**			
Electrical integrity	Electrical equipment installed to meet National Electrical Code area classification	**Y**		**9**	**8**	**72**
	Electrical switches labelled to identify equipment served	**Y**	**3**			
	Integrity of installed electrical equipment maintained	**Y**	**1**			
	Class I, division 2 installations provided with sealed devices Explosion proof equipment provided or purged reliably and good electrical isolation between hazardous and non hazardous areas	**Y**	**1**			
	All electrical equipment capable of being locked out	**N**	**0**			

	Disconnects provided, identified, inspected, and tested regularly	**Y**	**1**			
	Lighting securely installed and facilities properly grounded	**Y**	**1**			
Safety devices	Relief devices provided and relieving is to a safe area	**Y**	**3**	**8**	**7**	**56**
	Confidence that interlocks and alarms are operable	**Y**	**2**			
	Operating instructions are complete and current, and department has continued training and/or retaining program	**Y**	**2**			
	Safety devices are properly selected to match application	**Y**	**1**			
	Critical safety devices identified and included in regular testing program	**Y**	**1**			
	Fail safe instrumentation provided	**Y**	**1**			
Inerting and dip piping	Vessels handling flammables provided with dip pipes	**Y**	**2**	**10**	**5**	**50**
	Vessels handling flammables provided with reliable inerting system	**Y**	**2**			
	Effectiveness of inerting assured by regular inspection and testing	**Y**	**2**			
	Inerting instruction provided and understood	**Y**	**1**			

	Inerting system designed to cover routine and emergency startup	**Y**	**1**			
	Equipment ground visible and tested regularly	**Y**	**1**			
	Friction hot spots identified and monitored	**Y**	**1**			
Ventilation/Open construction	No flammables exist or open air construction is provided	**Y**	**3**	**10**	**4**	**40**
	Local ventilation provided to prevent unsafe levels of flammable, toxic, or obnoxious vapors	**Y**	**2**			
	Provision made for containing and controlling large spills and leaks of hazardous materials	**Y**	**2**			
	Building design provides for natural ventilation to prevent accumulation of dangerous vapors	**Y**	**1**			
	Sumps, pits, etc., nonexistent or else properly ventilated or monitored	**Y**	**1**			
	Equipment entry prohibited until safe atmosphere assured	**Y**	**1**			
Accessibility and/or separation	Critical shutdown devices and/or switches visible and accessible	**Y**	**2**	**9**	**2**	**18**
	Adjacent operations or services protected from exposure resulting from incident in concerned facility	**Y**	**2**			

	Operating personnel protected from hazards by location	**N**	**0**			
	Orderly spacing of equipment and materials within the concerned facility	**N**	**0**			
	Adjacent operations offer no hazard or exposure	**Y**	**1**			
	Hazardous operations within the facility well isolated	**Y**	**1**			

Table:4.12: Control Score Measure of Bibiyana South (400 MW)

Control Score
296

Table:4.13: Hazard Score Measure of Shahjibazar 86 MW Power Plant

Hazard Group	**Hazard**	**Finding**	**Rating points**	**Sum of rating points**	**Hazard Group Factor**	**Score**
Fire/explosion potential	Large inventory of flammables	**Y**	**2**	**9**	**10**	**90**
	Flammables generally distributed in the department rather than localized	**Y**	**2**			
	Flammables normally in vapor phase rather than liquid phase	**Y**	**2**			

	Systems opened routinely, allowing flammable/air mix, versus a totally closed system	**N**	**0**			
	Flammables having low flash points and high sensitivities	**Y**	**2**			
	Flammables heated and processed above flash point	**Y**	**1**			
Complexity of process	Need for precise reactant addition and control	**N**	**0**	**7**	**8**	**56**
	Considerable instrumentation requiring special operator understanding	**Y**	**2**			
	Troubleshooting by supervisor rather than operator	**Y**	**2**			
	Large number of operations and/or equipment monitored by one operator	**Y**	**1**			
	Complex layout of equipment and many control stations	**Y**	**1**			
	Difficult to startup or shutdown operations	**N**	**0**			
	Many critical operations to be maintained	**Y**	**1**			
Stability of process	Severity of uncontrolled situation	**Y**	**3**	**6**	**7**	**42**
	Materials that are sensitive to air, shock, heat, water, or other natural contaminants in the process	**Y**	**2**			

	Potential exists for uncontrolled reactions	**N**	**0**			
	Raw materials and finished goods that require special storage attention	**Y**	**1**			
	Intermediates that are thermally unstable	**N**	**0**			
	Obnoxious gases present or stored under pressure	**N**	**0**			
Operating pressure involved	Process pressure in excess of 110lb/in2 (gauge)	**Y**	**3**	**10**	**6**	**60**
	Process pressure above atmosphere but less than 110lb/in2 (gauge)	**Y**	**2**			
	Process pressure ranges from vacuum to atmospheric	**N**	**0**			
	Pressures are process rather than utility related	**Y**	**3**			
	High pressure situations are in operator	**Y**	**2**			
	Excessive sight glass application	**N**	**0**			
	Non-metallic materials of construction in pressure service	**N**	**0**			
Personnel/ environment	Exposure to process materials pose high potential for severe burn or severe health risks	**N**	**0**	**2**	**4**	**8**

hazard potential	Process materials corrosive to equipment	**N**	**0**			
	Potential for excursion above Threshold Limit Value (TLV)	**N**	**0**			
	Spills and/or flumes have high impact on equipment, people, or services	**Y**	**1**			
	High noise levels make communication difficult	**Y**	**1**			
High temperatures	Equipment temperatures exist in	**Y**	**1**	**3**	**2**	**6**
	Equipment temperatures exists in 100<170°C range	**N**	**0**			
	Equipment temperatures exists in 170<230°C range	**N**	**0**			
	High temperature situations are m operator-frequented area	**Y**	**2**			
	Overflows and/or leaks are fairly common	**N**	**0**			
	Heat Stress Possibilities from nature of work or ambient air	**N**	**0**			

Table:4.14: Hazard Score of Shahjibazar 86 MW Power Plant

Hazard Score
262

Table:4.15: Control Score Measure of Shahjibazar 86 MW Power Plant

Control Group	Control	Finding	Rating Points	Sum of rating points	Control Group Factor	Score
Fire protection	Automatic sprinkler system capable of meeting demands	**N**	**0**	**6**	**10**	**60**
	Supervisors and operators knowledgeable in installed fire protection systems are trained properly response to fire	**Y**	**2**			
	Adequate distribution of fire extinguishers	**Y**	**1**			
	Fire protection system inspected and tested with regular frequency	**Y**	**1**			
	Building and equipment provided with capability to isolate and control fire	**Y**	**1**			
	Special fire detection and protection provided where indicated	**Y**	**1**			
Electrical integrity	Electrical equipment installed to meet National Electrical Code area classification	**Y**	**3**	**8**	**8**	**64**
	Electrical switches labeled to identify equipment served	**Y**	**1**			
	Integrity of installed electrical equipment maintained	**Y**	**1**			
	Class I, division 2 installations provided with sealed devices Explosion proof equipment provided or purged reliably and good electrical isolation	**Y**	**1**			

	between hazardous and non hazardous areas					
	All electrical equipment capable of being locked out	**N**	**0**			
	Disconnects provided, identified, inspected, and tested regularly	**Y**	**1**			
	Lighting securely installed and facilities properly grounded	**Y**	**1**			
Safety devices	Relief devices provided and relieving is to a safe area	**Y**	**3**	**10**	**7**	**70**
	Confidence that interlocks and alarms are operable	**Y**	**2**			
	Operating instructions are complete and current, and department has continued training and/or retaining program	**Y**	**2**			
	Safety devices are properly selected to match application	**Y**	**1**			
	Critical safety devices identified and included in regular testing program	**Y**	**1**			
	Fail safe instrumentation provided	**Y**	**1**			
Inerting and dip piping	Vessels handling flammables provided with dip pipes	**Y**	**2**	**10**	**5**	**50**
	Vessels handling flammables provided with reliable inerting system	**Y**	**2**			

	Effectiveness of inerting assured by regular inspection and testing	**Y**	**2**			
	Inerting instruction provided and understood	**Y**	**1**			
	Inerting system designed to cover routine and emergency startup	**Y**	**1**			
	Equipment ground visible and tested regularly	**Y**	**1**			
	Friction hot spots identified and monitored	**Y**	**1**			
Ventilation/Open construction	No flammables exist or open air construction is provided	**Y**	**3**	**10**	**4**	**40**
	Local ventilation provided to prevent unsafe levels of flammable, toxic, or obnoxious vapors	**Y**	**2**			
	Provision made for containing and controlling large spills and leaks of hazardous materials	**N**	**2**			
	Building design provides for natural ventilation to prevent accumulation of dangerous vapors	**N**	**1**			
	Sumps, pits, etc., nonexistent or else properly ventilated or monitored	**Y**	**1**			
	Equipment entry prohibited until safe atmosphere assured	**Y**	**1**			

Accessibility and/or separation	Critical shutdown devices and/or switches visible and accessible	**Y**	**2**	**6**	**2**	**12**
	Adjacent operations or services protected from exposure resulting from incident in concerned facility	**Y**	**2**			
	Operating personnel protected from hazards by location	**N**	**0**			
	Orderly spacing of equipment and materials within the concerned facility	**N**	**0**			
	Adjacent operations offer no hazard or exposure	**Y**	**1**			
	Hazardous operations within the facility well isolated	**Y**	**1**			

Table:4.16: Control Score of Shahjibazar 86 MW Power Plant

Control Score
296

Table:4.17: Hazard Score Measure of Shahjibazar Power Plant 100MW(BPDB) ***(Closed)***

Hazard Group	**Hazard**	**Finding**	**Rating points**	**Sum of rating points**	**Hazard Group Factor**	**Score**
	Large inventory of flammables	**N**	**0**	**0**	**10**	**0**
	Flammables generally distributed in the department rather than localized	**N**	**0**			
	Flammables normally in vapor phase rather than liquid phase	**N**	**0**			
	Systems opened routinely, allowing flammable/air mix, versus a totally closed system	**N**	**0**			
	Flammables having low flash points and high sensitivities	**N**	**0**			
	Flammables heated and processed above flash point	**N**	**0**			
Complexity of process	Need for precise reactant addition and control	**N**	**0**	**0**	**8**	**0**
	Considerable instrumentation requiring special operator understanding	**N**	**0**			
	Troubleshooting by supervisor rather than operator	**N**	**0**			
	Large number of operations and/or equipment monitored by one operator	**N**	**0**			
	Complex layout of equipment and many control stations	**N**	**0**			

	Difficult to startup or shutdown operations	**N**	**0**			
	Many critical operations to be maintained	**N**	**0**			
Stability of process	Severity of uncontrolled situation	**N**	**0**	**0**	**7**	**0**
	Materials that are sensitive to air, shock, heat, water, or other natural contaminants in the process	**N**	**0**			
	Potential exists for uncontrolled reactions	**N**	**0**			
	Raw materials and finished goods that require special storage attention	**N**	**0**			
	Intermediates that are thermally unstable	**N**	**0**			
	Obnoxious gases present or stored under pressure	**N**	**0**			
Operating pressure involved	Process pressure in excess of 110lb/in2 (gauge)	**N**	**0**	**0**	**5**	**0**
	Process pressure above atmosphere but less than 110lb/in2 (gauge)	**N**	**0**			
	Process pressure ranges from vacuum to atmospheric	**N**	**0**			
	Pressures are process rather than utility related	**N**	**0**			

	High pressure situations are in operator	**N**	**0**			
	Excessive sight glass application	**N**	**0**			
	Non-metallic materials of construction in pressure service	**N**	**0**			
Personnel/ environment hazard potential	Exposure to process materials pose high potential for severe burn or severe health risks	**N**	**0**	**0**	**4**	**0**
	Process materials corrosive to equipment	**N**	**0**			
	Potential for excursion above Threshold Limit Value (TLV)	**N**	**0**			
	Spills and/or flumes have high impact on equipment, people, or services	**N**	**0**			
	High noise levels make communication difficult	**N**	**0**			
High temperatures	Equipment temperatures exist in	**N**	**0**	**0**	**2**	**0**
	Equipment temperatures exists in 100<170°C range	**N**	**0**			
	Equipment temperatures exists in 170<230°C range	**N**	**0**			
	High temperature situations are m operator-frequented area	**N**	**0**			
	Overflows and/or leaks are fairly common	**N**	**0**			

	Heat Stress Possibilities from nature of work or ambient air	**N**	**0**			

Table:4.18: Hazard Score Measure of Shahjibazar Power Plant 100MW(BPDB) ***(Closed)***

Hazard Score
0

Table:4.19: Control Score Measure of Shahjibazar Power Plant 100MW(BPDB) ***(Closed)***

Control Group	Control	Founding	Rating Points	Sum of rating points	Control Group Factor	Score
Fire protection	Automatic sprinkler system capable of meeting demands	**Y**	**4**	**9**	**10**	**90**
	Supervisors and operators knowledgeable in installed fire protection systems are trained properly response to fire	**Y**	**2**			
	Adequate distribution of fire extinguishers	**Y**	**1**			
	Fire protection system inspected and tested with regular frequency	**N**	**0**			
	Building and equipment provided with capability to isolate and control fire	**Y**	**1**			
	Special fire detection and protection provided where indicated	**Y**	**1**			

Electrical integrity	Electrical equipment installed to meet National Electrical Code area classification	**Y**	**3**	**15**	**8**	**120**
	Electrical switches labelled to identify equipment served	**Y**	**1**			
	Integrity of installed electrical equipment maintained	**Y**	**1**			
	Class I, division 2 installations provided with sealed devices Explosion proof equipment provided or purged reliably and good electrical isolation between hazardous and non hazardous areas	**Y**	**1**			
	All electrical equipment capable of being locked out	**Y**	**1**			
	Disconnects provided, identified, inspected, and tested regularly	**N**	**0**			
	Lighting securely installed and facilities properly grounded	**Y**	**1**			
Safety devices	Relief devices provided and relieving is to a safe area	**Y**	**3**	**7**	**7**	**49**
	Confidence that interlocks and alarms are operable	**Y**	**2**			
	Operating instructions are complete and current, and department has continued training and/or retaining program	**N**	**0**			
	Safety devices are properly selected to match application	**Y**	**1**			

	Critical safety devices identified and included in regular testing program	**N**	**0**			
	Fail safe instrumentation provided	**Y**	**1**			
Inerting and dip piping	Vessels handling flammables provided with dip pipes	**Y**	**2**	**7**	**5**	**35**
	Vessels handling flammables provided with reliable inerting system	**Y**	**2**			
	Effectiveness of inerting assured by regular inspection and testing	**N**	**0**			
	Inerting instruction provided and understood	**Y**	**1**			
	Inerting system designed to cover routine and emergency startup	**Y**	**1**			
	Equipment ground visible and tested regularly	**Y**	**1**			
	Friction hot spots identified and monitored	**N**	**0**			
Ventilation/Open construction	No flammables exist or open air construction is provided	**Y**	**3**	**9**	**4**	**36**
	Local ventilation provided to prevent unsafe levels of flammable, toxic, or obnoxious vapours	**Y**	**2**			
	Provision made for containing and controlling large spills and leaks of hazardous materials	**Y**	**2**			

	Building design provides for natural ventilation to prevent accumulation of dangerous vapours	**Y**	**1**			
	Sumps, pits, etc., non-existent or else properly ventilated or monitored	**N**	**0**			
	Equipment entry prohibited until safe atmosphere assured	**Y**	**1**			
Accessibility and/or separation	Critical shutdown devices and/or switches visible and accessible	**Y**	**2**	**9**	**2**	**18**
	Adjacent operations or services protected from exposure resulting from incident in concerned facility	**Y**	**2**			
	Operating personnel protected from hazards by location	**Y**	**2**			
	Orderly spacing of equipment and materials within the concerned facility	**Y**	**1**			
	Adjacent operations offer no hazard or exposure	**Y**	**1**			
	Hazardous operations within the facility well isolated	**Y**	**1**			

Table:4.20: Control Score of Shahjibazar Power Plant 100MW(BPDB) ***(Closed)***

Control Score
348

Table:4.21: Hazard Score Measure of Shahjibazar 70 MW Power Plant

Hazard Group	**Hazard**	**Finding**	**Rating points**	**Sum of rating points**	**Hazard Group Factor**	**Score**
Fire/explosion potential	Large inventory of flammables	**Y**	**2**	**8**	**10**	**80**
	Flammables generally distributed in the department rather than localized	**Y**	**2**			
	Flammables normally in vapor phase rather than liquid phase	**Y**	**2**			
	Systems opened routinely, allowing flammable/air mix, versus a totally closed system	**N**	**0**			
	Flammables having low flash points and high sensitivities	**Y**	**1**			
	Flammables heated and processed above flash point	**Y**	**1**			
Complexity of process	Need for precise reactant addition and control	**N**	**0**	**7**	**8**	**56**
	Considerable instrumentation requiring special operator understanding	**Y**	**2**			
	Troubleshooting by supervisor rather than operator	**Y**	**2**			
	Large number of operations and/or equipment monitored by one operator	**Y**	**1**			
	Complex layout of equipment and many control stations	**Y**	**1**			

	Difficult to startup or shutdown operations	**N**	**0**			
	Many critical operations to be maintained	**Y**	**1**			
Stability of process	Severity of uncontrolled situation	**Y**	**3**	**6**	**7**	**42**
	Materials that are sensitive to air, shock, heat, water, or other natural contaminants in the process	**Y**	**2**			
	Potential exists for uncontrolled reactions	**N**	**0**			
	Raw materials and finished goods that require special storage attention	**Y**	**1**			
	Intermediates that are thermally unstable	**N**	**0**			
	Obnoxious gases present or stored under pressure	**N**	**0**			
Operating pressure involved	Process pressure in excess of 110lb/in2 (gauge)	**Y**	**3**	**8**	**6**	**48**
	Process pressure above atmosphere but less than 110lb/in2 (gauge)	**N**	**0**			
	Process pressure ranges from vacuum to atmospheric	**N**	**0**			
	Pressures are process rather than utility related	**Y**	**3**			

	High pressure situations are in operator	**Y**	**2**			
	Excessive sight glass application	**N**	**0**			
	Non-metallic materials of construction in pressure service	**N**	**0**			
Personnel/ environment hazard potential	Exposure to process materials pose high potential for severe burn or severe health risks	**N**	**0**	**3**	**4**	**12**
	Process materials corrosive to equipment	**Y**	**2**			
	Potential for excursion above Threshold Limit Value (TLV)	**N**	**0**			
	Spills and/or flumes have high impact on equipment, people, or services	**Y**	**1**			
	High noise levels make communication difficult	**N**	**0**			
High temperatures	Equipment temperatures exist in	**Y**	**1**	**1**	**2**	**2**
	Equipment temperatures exists in 100<170°C range	**N**	**0**			
	Equipment temperatures exists in 170<230°C range	**N**	**0**			
	High temperature situations are m operator-frequented area	**N**	**0**			

	Overflows and/or leaks are fairly common	**N**	**0**			
	Heat Stress Possibilities from nature of work or ambient air	**N**	**0**			

Table 4.22: Hazard score of Shahjibazar 70 MW Power Plant

Hazard Score
248

Table:4.23: Control Score Measure Shahjibazar 70 MW Power Plant

Control Group	Control	Finding	Rating Points	Sum of rating points	Control Group Factor	Score
Fire protection	Automatic sprinkler system capable of meeting demands	**N**	**0**	**5**	**10**	**50**
	Supervisors and operators knowledgeable in installed fire protection systems are trained properly response to fire	**Y**	**2**			
	Adequate distribution of fire extinguishers	**Y**	**1**			
	Fire protection system inspected and tested with regular frequency	**Y**	**1**			
	Building and equipment provided with capability to isolate and control fire	**Y**	**1**			

	Special fire detection and protection provided where indicated	**N**	**0**			
Electrical integrity	Electrical equipment installed to meet National Electrical Code area classification	**Y**	**3**	**9**	**8**	**72**
	Electrical switches labeled to identify equipment served	**Y**	**1**			
	Integrity of installed electrical equipment maintained	**Y**	**1**			
	Class I, division 2 installations provided with sealed devices Explosion proof equipment provided or purged reliably and good electrical isolation between hazardous and non-hazardous areas	**Y**	**1**			
	All electrical equipment capable of being locked out	**Y**	**1**			
	Disconnects provided, identified, inspected, and tested regularly	**Y**	**1**			
	Lighting securely installed and facilities properly grounded	**Y**	**1**			
Safety devices	Relief devices provided and relieving is to a safe area	**Y**	**3**	**10**	**7**	**70**
	Confidence that interlocks and alarms are operable	**Y**	**2**			
	Operating instructions are complete and current, and department has continued training and/or retaining program	**Y**	**2**			

	Safety devices are properly selected to match application	**Y**	**1**			
	Critical safety devices identified and included in regular testing program	**Y**	**1**			
	Fail safe instrumentation provided	**Y**	**1**			
Inerting and dip piping	Vessels handling flammables provided with dip pipes	**Y**	**2**	**10**	**5**	**50**
	Vessels handling flammables provided with reliable inerting system	**Y**	**2**			
	Effectiveness of inerting assured by regular inspection and testing	**Y**	**2**			
	Inerting instruction provided and understood	**Y**	**1**			
	Inerting system designed to cover routine and emergency startup	**Y**	**1**			
	Equipment ground visible and tested regularly	**Y**	**1**			
	Friction hot spots identified and monitored	**Y**	**1**			
Ventilation/Open construction	No flammables exist or open air construction is provided	**Y**	**3**	**9**	**4**	**36**
	Local ventilation provided to prevent unsafe levels of flammable, toxic, or obnoxious vapors	**Y**	**2**			

	Provision made for containing and controlling large spills and leaks of hazardous materials	**Y**	**2**			
	Building design provides for natural ventilation to prevent accumulation of dangerous vapors	**Y**	**1**			
	Sumps, pits, etc., nonexistent or else properly ventilated or monitored	**N**	**0**			
	Equipment entry prohibited until safe atmosphere assured	**Y**	**1**			
Accessibility and/or separation	Critical shutdown devices and/or switches visible and accessible	**Y**	**2**	**9**	**2**	**18**
	Adjacent operations or services protected from exposure resulting from incident in concerned facility	**Y**	**2**			
	Operating personnel protected from hazards by location	**Y**	**2**			
	Orderly spacing of equipment and materials within the concerned facility	**Y**	**1**			
	Adjacent operations offer no hazard or exposure	**Y**	**1**			
	Hazardous operations within the facility well isolated	**Y**	**1**			

Table:4.24: Control Score Measure Shahjibazar 70 MW Power Plant

Control Score
296

4.2 Results

The checklists were filled by doing a field survey on CMSs in Jalalabad Gas Transmission and Distribution System Limited. All the response and data were collected in person. The checklist with the data input are shown in Table:4.1, Table:4.2, Table:4.3, Table:4.4, Table:4.5, Table:4.6, Table:4.7, Table:4.8, Table:4.9, Table:4.10, Table:4.11, Table:4.12, Table:4.13, Table:4.14, Table:4.15, Table:4.16, Table:4.17, Table:4.18, Table:4.19, Table:4.20, Table:4.21, Table:4.22, Table:4.23, Table:4.24.

Table:4.1, Table:4.3 shows the data input of Bibiyana 3 (400 MW) Power Plant and Table:4.2, Table:4.4 shows the evaluation result of hazard score from table:4.1, and control score of Table:4.3 respectively. Similarly, Table:4.5, Table:4.7 shows the data input of Summit Bibiyana (341 MW) and Table:4.6, Table:4.8 shows the evaluation result of hazard score from table:4.5, and control score of Table:4.7 respectively. Again, Table:4.9, Table:4.11 shows the data input of Bibiyana South (400 MW) and Table:4.10, Table:4.12 shows the evaluation result of hazard score from table:4.9, and control score of Table:4.11 respectively. Therefore, Table:4.13, Table:4.15 shows the data input of Shahjibazar 86 MW Power Plant and Table:4.14, Table:4.16 shows the evaluation result of hazard score from table:4.13, and control score of Table:4.15 respectively. Again, Table:4.17, Table:4.19 shows the data input of Shahjibazar Power Plant 100MW(BPDB) and Table:4.18, Table:4.20 shows the evaluation result of hazard score from table:4.17, and control score of Table:4.19 respectively. Table:4.21, Table:4.23 shows the data input of Shahjibazar 70 MW Power Plant and Table:4.22, Table:4.24 shows the evaluation result of hazard score from table:4.21, and control score of Table:4.23 respectively.

4.3 Hazard and Control Score Comparison:

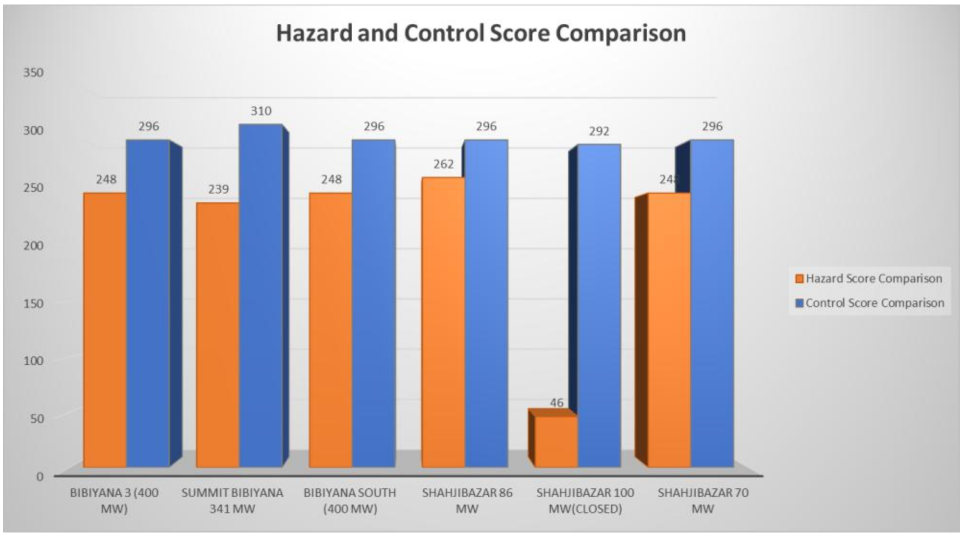

Figure:4.1 Graphical Comparison between hazard and control scores among the CMSs.

4.4 Graphical Analysis of Hazard Scores:

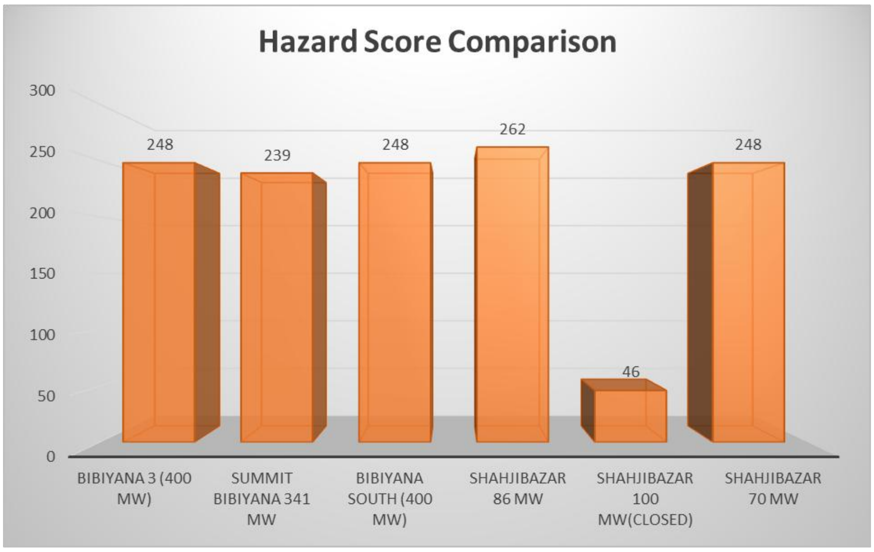

Figure:4.2 Total Hazard Score Comparison among the CMSs.

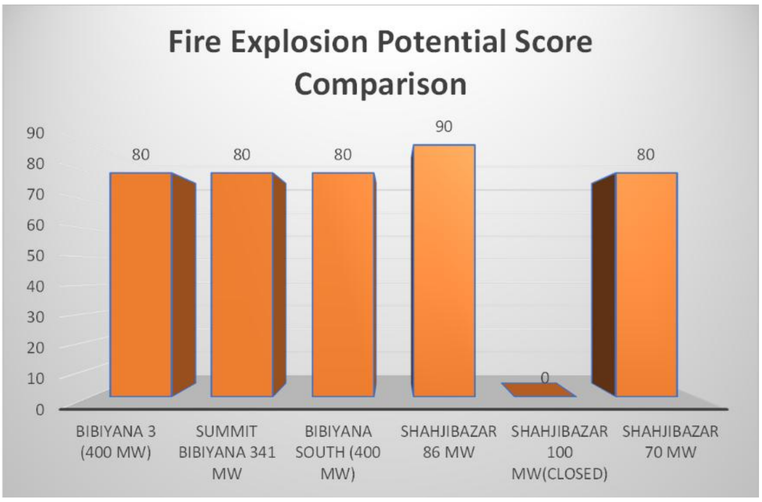

Figure:4.3 Fire Explosion Potential Score Comparison among the CMSs.

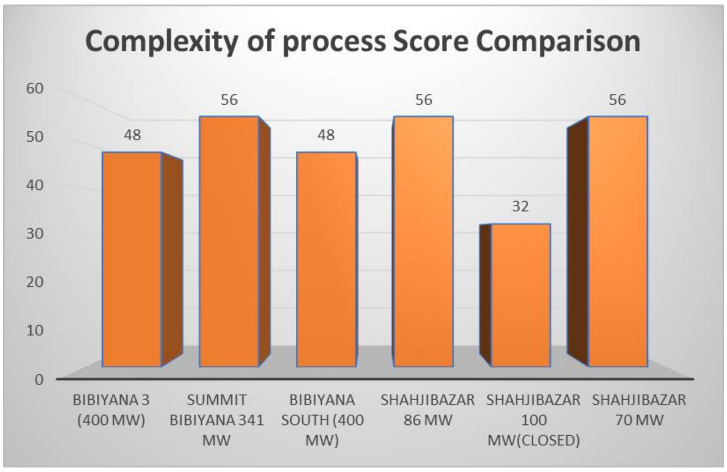

Figure:4.4 Complexity of process Score Comparison among the CMSs.

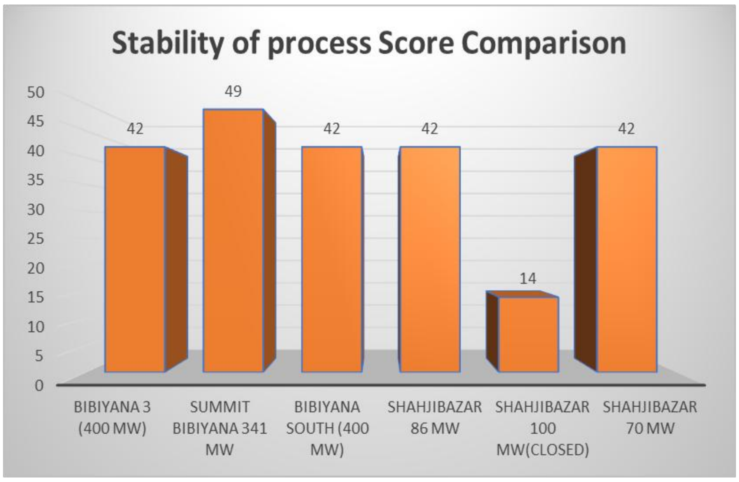

Figure:4.5 Stability of process Score Comparison among the CMSs.

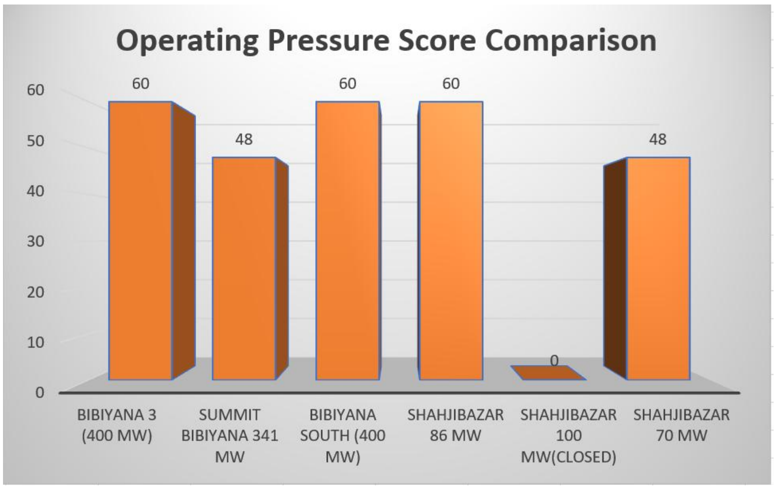

Figure:4.6 Operating Pressure Score Comparison among the CMSs.

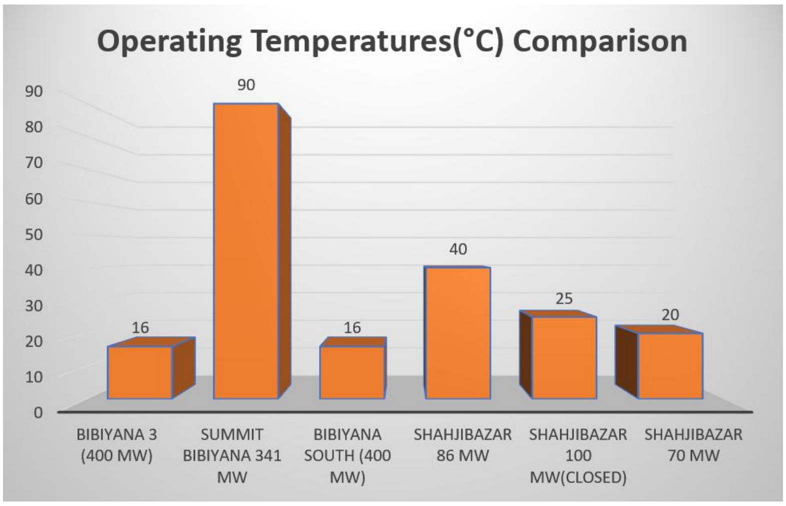

Figure:4.7 Operating Pressure Comparison among the CMSs.

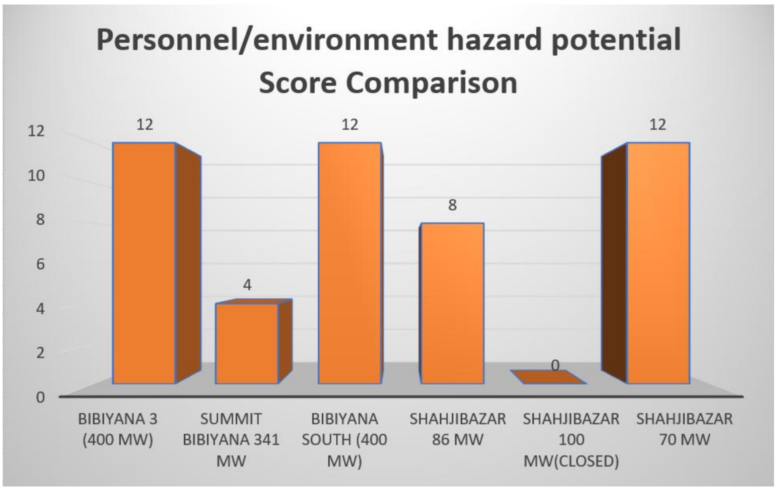

Figure:4.8 Personnel/environment hazard potential Score Comparison among the CMSs.

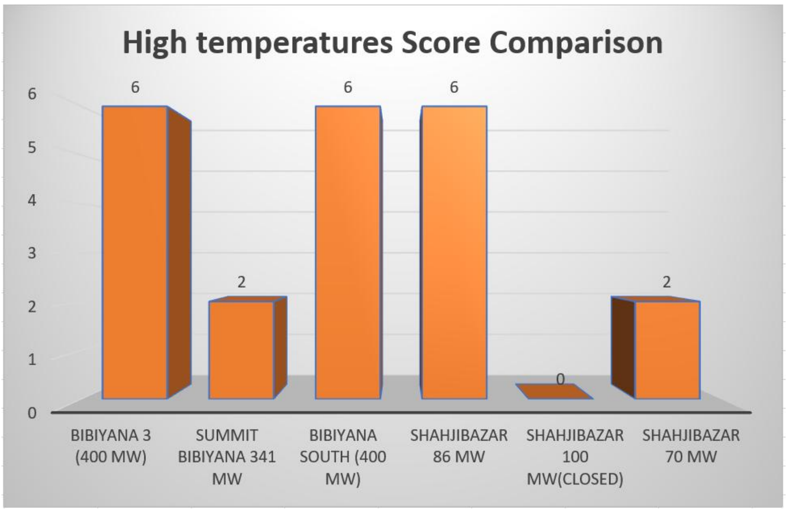

Figure:4.9 High Temperature Score Comparison among the CMSs.

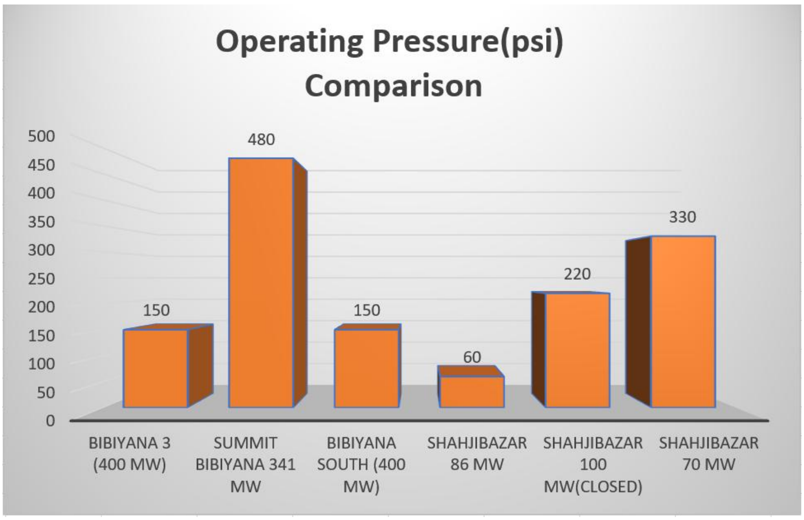

Figure:4.10 Operating Temperature Comparison among the CMSs.

4.5 Graphical Description of Control Scores:

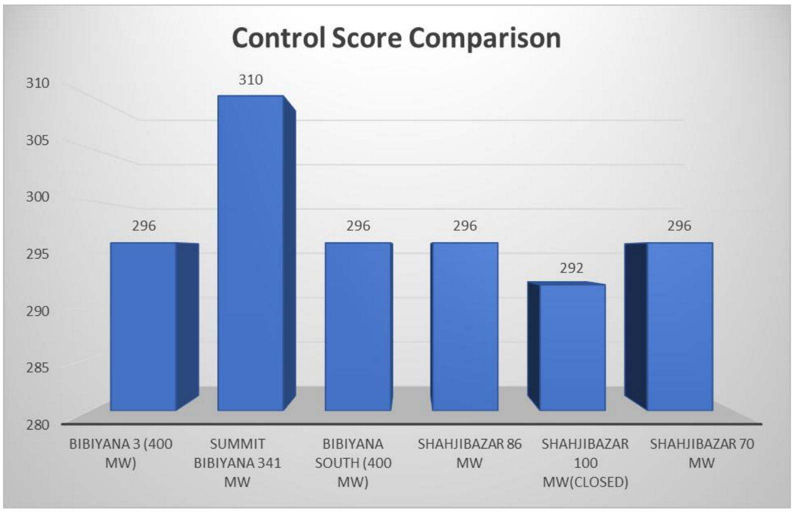

Figure:4.11 Total Control Score Comparison among the CMSs.

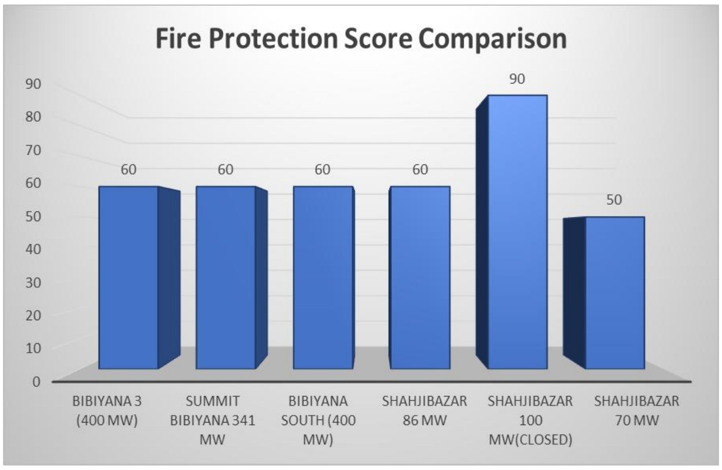

Figure:4.12 Fire Protection Score Comparison among the CMSs.

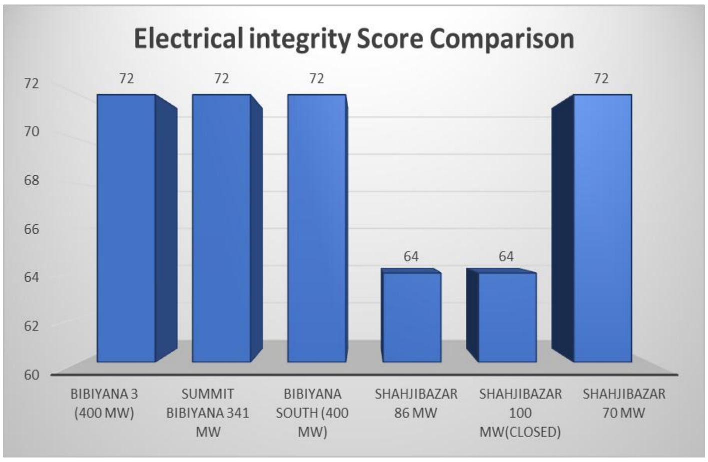

Figure:4.13 Electrical integrity Score Comparison among the CMSs.

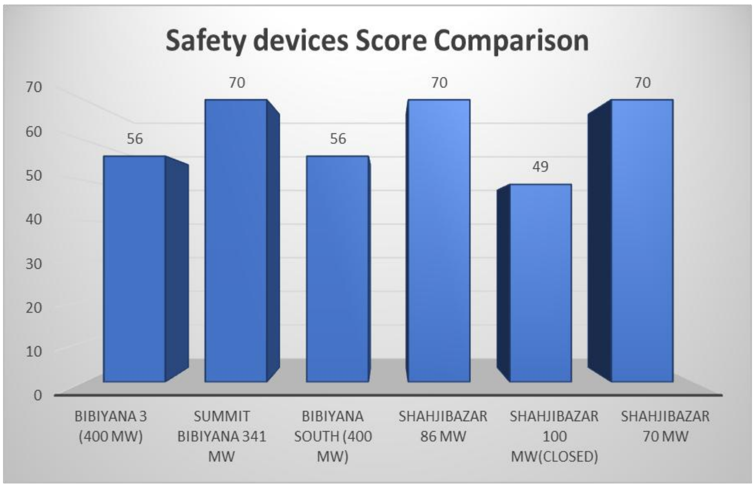

Figure:4.14 Safety devices Score Comparison among the CMSs.

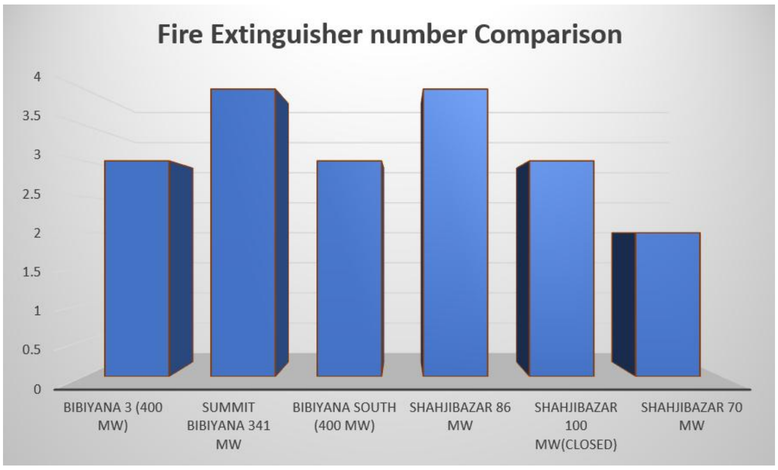

Figure:4.15 Fire Extinguisher number Comparison among the CMSs.

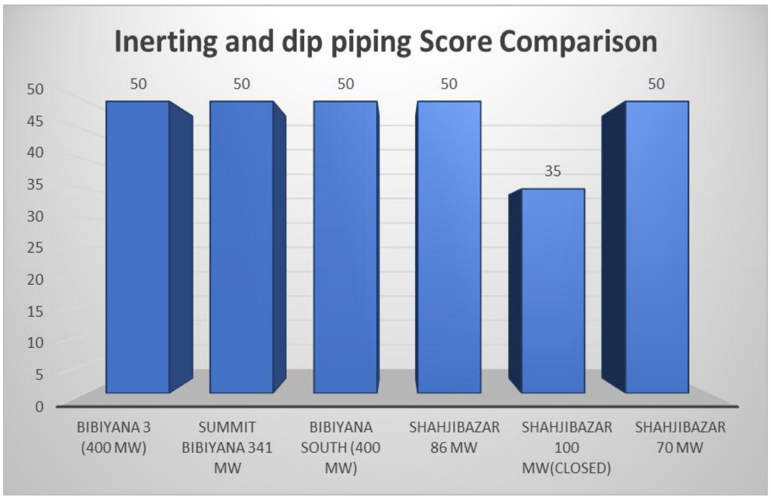

Figure:4.16 Inerting and dip piping Comparison among the CMSs.

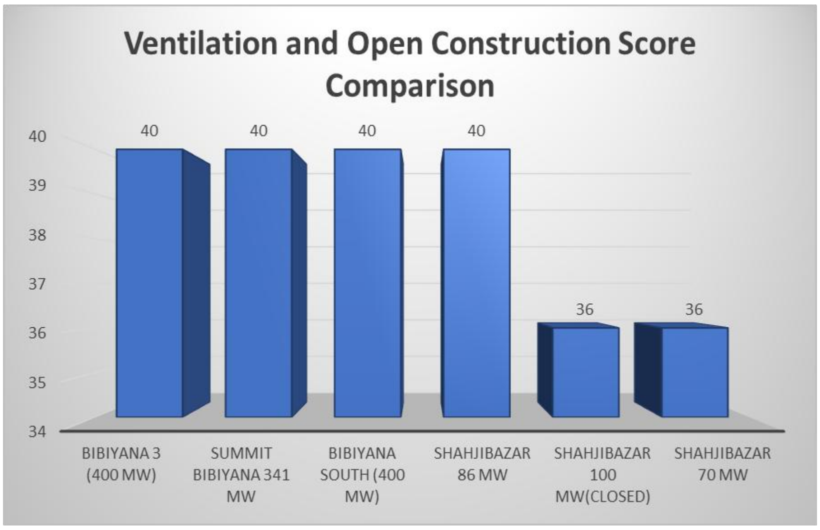

Figure:4.17 Ventilation and Open Construction Score Comparison among the CMSs.

Figure:4.18 Accessibility Score Comparison among the CMSs.

Chapter-5

Discussion

5.1 Risk Comparison Between the CMSs

5.1.1 Risk Index and Relative Risk determination

Table:5.1 Risk Index and Relative Risk determining chart.

Exposure unit	Hazard Score	Control Score	Risk Index	Relative Risk	%Risk Index
Bibiyana 3 (400 MW)	248	296	48	-23	-13.60946746
Summit Bibiyana 341 MW	239	310	71	0	0
Bibiyana South (400 MW)	248	296	48	-23	-13.60946746
Shahjibazar 86 MW	262	296	34	-37	-21.89349112
Shahjibazar 100 MW(closed)	46	292	246 (non considerable)	(non considerable)	-42.01183432
Shahjibazar 70 MW	248	296	56	-15	-8.875739645
				= -169	= 100%

5.1.2 Composite Risk determination and Risk Ranking

Table 5.2: Composite Risk determination and Risk Ranking

Exposure unit	%Risk Index	Composite Exposure ($)	Composite Risk ($)	Risk Ranking
Bibiyana 3 (400 MW)	-13.60946746	2465610	335556.3905	**1**
Summit Bibiyana 341 MW	0	2629984	0	**5**
Bibiyana South (400 MW)	-13.60946746	2383423	324371.1775	**2**
Shahjibazar 86 MW	-21.89349112	821870	179936.0355	**3**
Shahjibazar 100 MW(closed)	-42.01183432 (non considerable)	1479366 (non considerable)	621508.7929	**(Non-Considerable)**
Shahjibazar 70 MW	-8.875739645	1643740	145894.0828	**4**

5.1.3 Overview of the total calculation and ranking:

Table 5.3: Overview of the total calculation and ranking:

Exposure unit	Hazard Score	Control Score	Risk Index	Relative Risk	%Risk Index	Composite Exposure ($)	Composite Risk	Risk Ranking
Bibiyana 3 (400 MW)	248	296	48	-23	-13.609467	2465610	335556.3905	**1**
Summit Bibiyana 341 MW	239	310	71	0	0	2629984	0	**5**
Bibiyana South (400 MW)	248	296	48	-23	-13.609467	2383423	324371.1775	**2**
Shahjibazar 86 MW	262	296	34	-37	-21.893491	821870	179936.0355	**3**
Shahjibazar 100 MW (closed)	46	**292**	246	-71 (non considerable)	-42.011834 (non considerable)	1479366	621508.7929 (non considerable)	**(Non considerable)**
Shahjibazar 70 MW	248	296	56	-15	-8.8757396	1643740	145894.0828	**4**

Graphical Comparison of the risk index of the CMSs is shown in figure:4.19 and the total risk index contribution is shown in figure:4.20.

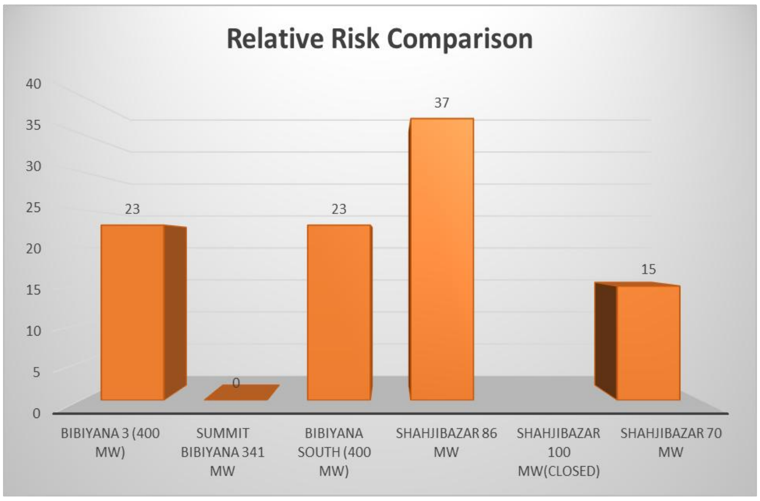

Figure5.1: Graphical Comparison of the risk index of the CMSs.

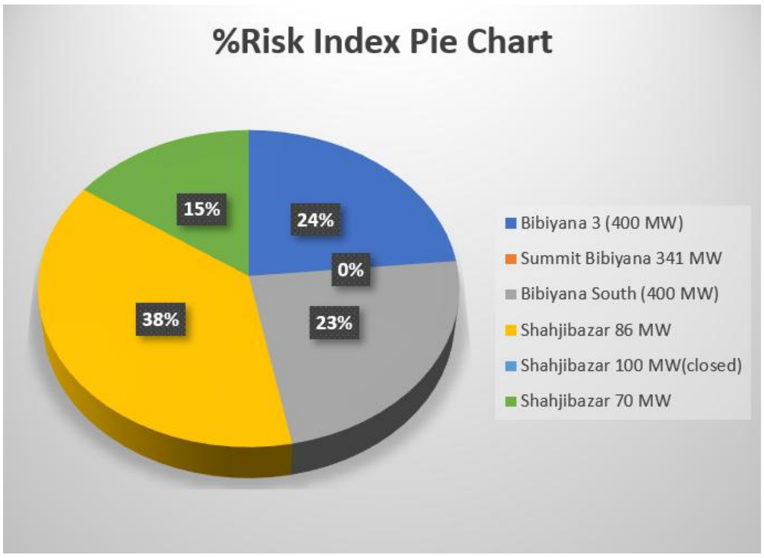

Figure 5.2: Pie Chart Showing the %risk index of the CMSs.

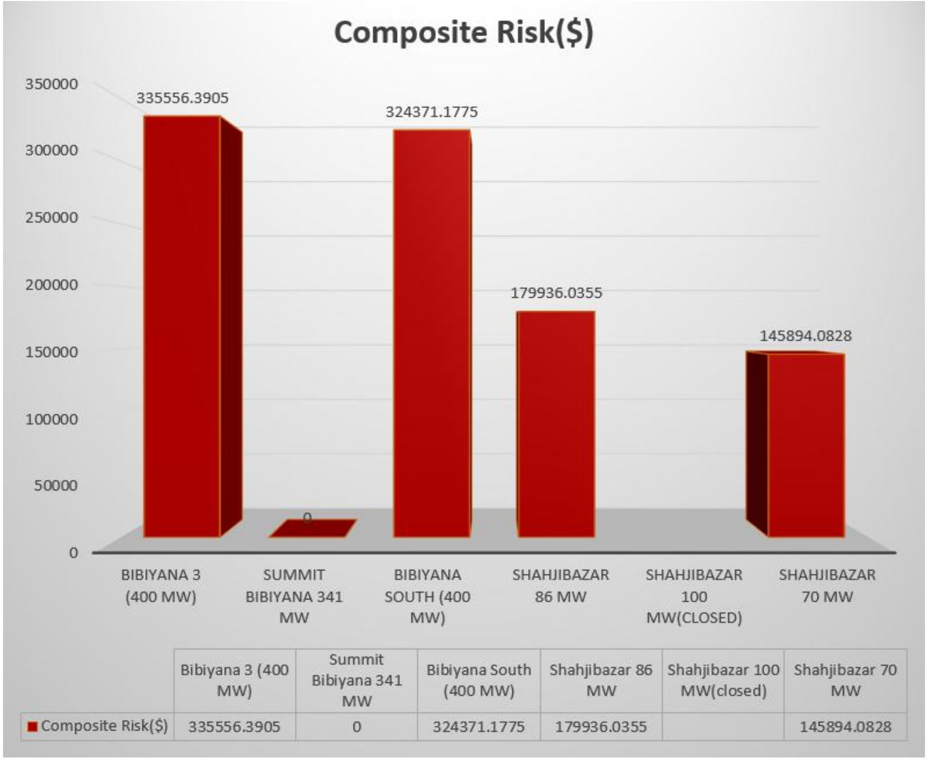

Figure 5.3: Composite Risk Comparisons of the CMSs.

Among the six studied CMSs, the highest composite risk has been calculated from The Bibiyana 3 Power Plant (400 MW), under Nabiganj Upazila in Habiganj District, Sylhet Division and the amount of Composite risk is 335556.3905. The second highest composite risk has been evaluated from Bibiyana South Combined-Cycle Power Plant**,** (400 MW) which is 324371.1775. The third and the fourth highest composite risk have been evaluated in Shahjibazar 86 MW Gas Power Plant and Shahjibazar 70 MW (BPDB) Gas Power Plant which are 179936.0355 and 145894.0828 respectively. Finally, the least composite risk has been evaluated in Summit Bibiyana Power Plant, Habiganj, Sylhet and the amount of Composite risk is 0.

The composite risk in Summit Bibiyana Power Plant is 0 because of it has the highest risk index or the highest positive value or highest subtraction of the hazard score from the control score than any other CMS and was taken as the “base reference”. Therefore, all curves were normalized with respect to the best CMS unit and it was done by subtracting the risk score of the best unit from the risk score of the concerned unit. Thus, this adjustment made the relative risk of the best unit as 0, so do the %risk index and the composite risk.

I’ve found some hazards through the analysis that are responsible for increasing the composite risk of each CMS and will be pointing out those hazards and the consequences.

5.2 Bibiyana 3 Power Plant (400 MW), Habiganj, Sylhet

With the highest composite risk, Bibiyana 3 Power Plant ranked no. 1. By analyzing the data, we get to know, the hazard score and the control score has a lesser difference. This indicates that, either proper control measures need to be taken or we need to reduce the hazard. Bibiyana 3 Power Plant on the hazard group, has a very good fire explosion potential, a moderate complexity of process, a very good process stability, a moderate process pressure involvement, a moderate personal/environmental hazard potential and a lowest high temperature situation. On the counterpart, in the control group measures, Bibiyana 3 Power Plant has a good fire protection measure, a very good electrical integrity, a very good safety devices measures, a moderate inerting and dip piping system, a greater ventilation or open construction system and a greater accessibility and separation measures.

5.3 Bibiyana South Combined-Cycle Power Plant, (400 MW)

With the second highest composite risk, Bibiyana South Power Plant**,** ranked no. 2. By analyzing the data, we get to know, the hazard score and the control score has the same difference as Bibiyana South Power Plant CMS. The control score is much higher than hazard score. The plant has a good fire explosion potential, a moderate complexity of process, a very good process stability, a moderate process pressure involvement, a moderate personal/environmental hazard potential and a lowest high temperature situation.

On the counterpart, in the control group measures, Bibiyana South Power Plant has a good fire protection measure, a very good electrical integrity, a very good safety devices measures, a moderate inerting and dip piping system, a greater ventilation or open construction system and a greater accessibility and separation measures.

5.4 Shahjibazar 86 MW Gas Power Plant

With a moderate composite risk, Shahjibazar 86 MW Gas Power Plant ranked no. 3. By analyzing the data, we get to know, the hazard score and the control score has the least difference here. This indicates that, either proper control measures need to be taken or we need to reduce the hazard. Shahjibazar 86 MW Power Plant on the hazard group, has the highest good fire explosion potential, a moderate complexity of process, a lower process stability, a moderate process pressure involvement, a moderate personal/environmental hazard potential and a moderate high temperature situation.

On the counterpart, in the control group measures, Shahjibazar 86 MW Power Plant has a good fire protection measure, a very good electrical integrity, a greater safety devices measures, a lower inerting and dip piping system, a very good ventilation or open construction system and a greater accessibility and separation measures.

5.5 Shahjibazar 70 MW (BPDB) Gas Power Plant

With a moderate composite risk, Shahjibazar 70 MW Gas Power Plant ranked no. 4. By analyzing the data, we get to know, the hazard score and the control score has lesser difference here. Shahjibazar 70 MW Power Plant on the hazard group, has the highest good fire explosion potential, a moderate complexity of process, a lower process stability, a moderate process pressure involvement, a moderate personal/environmental hazard potential and a moderate high temperature situation.

On the counterpart, in the control group measures, Shahjibazar 70 MW Power Plant has a good fire protection measure, a very good electrical integrity, a greater safety devices measures, a lower inerting and dip piping system, a very good ventilation or open construction system and a greater accessibility and separation measures.

5.6 Summit Bibiyana Power Plant, Habiganj, Sylhet

With the lowest composite risk Summit Bibiyana Power Plant ranked no. 5. By analyzing the data, we get to know, the hazard score and the control score has a quite good difference. Having a moderate hazard potential score and a good control score, indicates that, proper control measures have been taken and still we need to continue reducing the hazard by taking more control measures Summit Bibiyana Power Plant on the hazard group, has a very good fire explosion potential, a moderate complexity of process, a lower process stability, a moderate process pressure involvement, a moderate personal/environmental hazard potential and a lowest high temperature situation.

On the contrary, in the control group measures, Summit Bibiyana Power Plant has a moderate fire protection measure, a very good electrical integrity, a greater safety devices measures, a lower inerting and dip piping system, a good ventilation or open construction system and a moderate accessibility and separation measures.

5.7 Shahjibazar 100 MW Gas Turbine Power Plant, BPDB

This CMS is currently out of operation due to an equipment malfunction at its associated industry. Therefore, it was not considered in the risk calculation. However, relevant data for this CMS have been recorded. As it remained closed, the components of the hazard group were not documented, although the components of the control group were found to be noteworthy.

In the control group measures, Shahjibazar 100MW has a moderate fire protection measure, a very good electrical integrity, a greater safety devices measures, a good inerting and dip piping system, a moderate ventilation or open construction system and a moderate accessibility and separation measures.

Chapter-6

Conclusion

6.1 Conclusion

Risk Assessment of the CMSs includes the study of infrastructure and the significance of CMSs in terms of distributing NG. The research work has been carried to see the assessment of risk sources and control measures taken to prevent the accident from occurring.

Based on the results and discussions presented, it is evident that the application of Frank and Morgan's Logical Risk Analysis framework has provided valuable insights into the risk profiles of the studied CMSs. The analysis revealed significant variations in composite risk levels among the six CMSs, with the highest composite risk observed at the Bibiyana-3 (400 MW) combined Cycle Power Plant.

The identified composite risk scores serve as indicators of the overall risk magnitude associated with each CMS, enabling stakeholders to prioritize risk management efforts effectively. Among the CMSs, Bibiyana 3 and Bibiyana South Power Plants have exhibited considerable composite risks, highlighting the importance of implementing effective risk mitigation procedures.

Due to its efficient control mechanisms and comparatively low hazard potential, it is noteworthy that Summit Bibiyana (341 MW) Power Station CMS showed the lowest composite risk. The importance of proactive risk management techniques in lowering overall risk levels across CMS operations is highlighted by this.

The identification of specific hazards contributing to the composite risk levels of each CMS unveils actionable insights for targeted risk mitigation efforts. From fire explosion potential to process stability and environmental hazard potential, the delineated hazards elucidate critical focal points for intervention. By addressing these vulnerabilities and bolstering control measures, organizations can bolster their capacity to primitively identify and mitigate risks, thereby fostering a culture of safety and resilience within CMS operations.

Stakeholders can utilize the insights gained from this analysis to develop targeted risk management plans tailored to the unique characteristics and challenges of each CMS. By focusing on hazard mitigation strategies and strengthening control measures, organizations can minimize the likelihood and severity of adverse events, ultimately safeguarding personnel, assets, and the surrounding environment.

The application of Logical Risk Analysis framework has facilitated a comprehensive assessment of risk profiles within the studied CMSs, enabling informed decision-making and proactive risk management practices. By integrating risk analysis methodologies with practical insights, organizations can enhance their resilience to potential hazards and ensure the continued safe and efficient operation of CMS facilities.

6.2 Recommendation

We provide some recommendation to improve the facilities:

1. Construction regulations should be maintained.
2. Routine training and workshops should be carried to the operators.
3. Enough safety devices and fire extinguishers should be in place.
4. Awareness for any unpleasant situation is a must.

6.3 Limitation

The research work has been satisfactory. But we faced some limitations. As mentioned below:

1. If it was possible to conduct more CMS survey and data collection, the results would have been significant.
2. Some data are taken hypothetically as the real data were not available.

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