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IDENTIFICATION AND SIMULATION OF FIRE AND EXPLOSION HAZARDS USING HAZOP AND ALOHA, CASE STUDY: THE IGNITION SYSTEM OF A POWER PLANT

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Abstract: A power plant is widely recognized as a high-risk industrial environment due to the complex processes and potential exposure to hazardous materials, high temperatures, and powerful machinery. In the meantime, identifying fire and explosion hazards is vital to preventing catastrophic incidents, safeguarding lives and assets, and ensuring the safe, compliant operation of process plants. This study investigates fire and explosion hazards associated with the ignition system of a power plant situated in northern Iran. Hazard identification was performed using the HAZOP technique, while risk levels were assessed and prioritized through a Decision Matrix Risk Assessment (DMRA). To visualize the severity of potential hazards, the ALOHA software was employed for consequence modeling. The most important identified risk was a temperature deviation failure in the control system of the vaporizer burner. Installing a temperature indicator on the vaporizer outlet line is recommended to assist operators and supervisors in detecting and preventing such deviation and its potential consequences. The results of ALOHA indicate that the resulting explosion and radiation levels, along with potential domino effects, pose a significant threat to human life.

Keywords: ALOHA, HAZOP, Ignition system, Powerplant

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1. Introduction

A power plant is an arrangement of systems and subsystems that produce electricity (Raja et al., 2006). Most power plants utilize one or more generators to convert mechanical energy into electrical energy. Power stations are of significant importance in fulfilling the increasing need for electricity. The various techniques utilized by power generation facilities, such as thermal, hydroelectric, nuclear, and sustainable energy methodologies, play a role in ensuring the accessibility of electricity for residential, commercial, and industrial purposes. The majority of power facilities globally rely on the combustion of fossil fuels like coal, oil, and natural gas for the production of electrical energy (Alsaffar and Ezzat, 2020).

Natural gas power plants create electricity by using natural gas as a fuel. There are various types of natural gas power plants that produce electricity yet serve different objectives. All natural gas plants employ a gas turbine, natural gas is combined with a stream of air, which combusts and expands through the turbine, causing a generator to spin a magnet, producing electricity. Power stations are intricate settings that contain high-voltage machinery, combustible substances, and dangerous chemicals. An instantaneous deviation from safety procedures or malfunction of equipment can lead to severe outcomes, including casualties, fatalities, and substantial harm to infrastructure.in result a power plant considered as a high-risk workplace, requiring safe working procedures due to the nature of the operations and employment.

The safety of natural gas power generation has become a critical component of city public safety. Therefore, this workplace is prone to potential accidents due to the stringent operating procedures of the power plant. The outcome may have an influence on the residents around the Power Plant and societal stability. It even can result in major accidents, deaths and wounds (Shao and Duan, 2012). Despite the enhanced safety measures in power plants compared to previous years, employees in these facilities continue to face various risks.so it is necessary to devise a strategy that includes the identification and evaluation of major risks in order to complete the necessary steps in determining and implementing risk identification elements during plant operation (Sinpong, 2015). According to the International Labor Organization (ILO), there are 3 million workplace deaths annually. This means that every day, 8,219 workers die due to accidents or work-related diseases. (ILO, 2023). Furthermore, according to the OECD (2008), over 2,500 fatalities occur annually in energy-related plants as a result of severe accidents (OECD, 2008). This figure seems to be increasing annually in correlation with the growing demand for energy consumption. Given the hazardous nature of power plant workplaces, companies are required to ensure safe working conditions by implementing systematic and regular processes for hazard identification and risk assessment (Ahmad et al., 2016). Fire and Explosion are the most predominant incidents occurring in chemical and process industries, potentially resulting in significant property damage and production losses. It is widely acknowledged that fire and explosion hazards rank as the primary and secondary major hazards within the chemical sector (Ahmadi and Galenovi, 2011). Fire is the most prevalent, but explosions are more damaging, typically resulting in fatalities and property damage (Khan and Abbasi, 2001). Fire can result in human fatalities, major injuries, financial losses due to equipment damage and disruption of productive activity, job loss, and possibly irreversible environmental damage, as well as increased insurance premiums. Fire safety within power plant operations is of utmost importance owing to the existence of extremely flammable substances and the risk of electrical sparks. In order to reduce the likelihood of fires, power plants are required to follow rigorous safety procedures. Hence identifying risk factors and measures to prevent fire and explosion mishaps in these industries is critical (Etowa et al., 2002).

Identifying hazard is critical for the safe design and operation of systems in process plants and other facilities. There are several approaches for identifying hazardous circumstances, all of which must be rigorously, thoroughly, and systematically applied by a multidisciplinary team of professionals. Success is determined by first identifying and then analyzing potential scenarios that could result in accidents of varying severity. Without a structured identification system, risks can be overlooked, resulting in incomplete risk assessments and eventual loss. Risk assessment is crucial, encompassing stages such as hazard identification, analysis, and risk evaluation. Various simulation programs are also utilized to assess the potential effects of hazards. Hazard and Operability Analysis (HAZOP) is widely recognized as a preferred technique for identifying hazards and ranking risks in hazardous facilities (Djapan et al., 2018). The HAZOP technique is a cornerstone in process safety review methodologies for effective risk management. Experience has demonstrated its efficacy in identifying hazards and critical control points, prioritizing them for effective control measures. The identification of hazards through HAZOP allows for a systematic assessment and critique of the process. Therefore, these techniques can be considered effective for recognizing and predicting hazards, potentially increasing safety levels, preventing accidents, and enhancing system reliability by minimizing operational issues. Conversely, prioritizing risks can enable managers to take action to reduce or eliminate the most pressing risk factors, thereby safeguarding workers' health through the implementation of crucial safety measures. Through HAZOP analysis, operators can efficiently locate essential documents to address abnormal situations (Alaei et al., 2014). On the other hand, decision matrix risk assessment (DMRA) is a systematic and widely used approach for risk estimation that entails assessing and categorizing risks based on informed judgements about probability, consequence, and relative importance (Reniers et al., 2005). In the same direction the use of software such as Areal Location of Hazardous Atmosphere (ALOHA), PHAST, FLASC is increasing day by day in order to determine the impact distances of VCE explosions and toxic dispersion. ALOHA is a software program specifically developed for modeling toxic hazards resulting from chemical releases, thermal radiation emitted by chemical fires, and scenarios involving vapor explosions, as part of risk assessments for both human safety and environmental impact (Ilic et al., 2018).

2. Materials and Methods

2.1. Case Study

The study has conducted at a power plant in northern Iran. The plant consists of six gas units each with a capacity of 159 MW at ISO conditions and the output of Power Plant is almost 6,491,255 MW per hour in the year.

The power plant under study comprises various process units and facilities, including the fuel oil system, natural gas system, ignition liquid gas system, hydraulic oil system, and gas turbine with drainage gas. Natural gas, fuel gas, and fuel oil are the primary chemical materials stored and utilized in these facilities, serving as fuel for turbine units to generate electrical energy.

2.2. Ignition System Unit Description

Ignition gas is used at gas turbine start-up to produce flames and thus igniting the main fuel. The natural gas system supplies the flow of natural gas required for formation of ignition flames taken from the main fuel gas supply line at GT skid. The ignition gas used for fuel oil start-up is propane (or a mixture of propane and butane). The main parts of the ignition systems are a tank, two vaporizers and pipes are given in Figure 1.

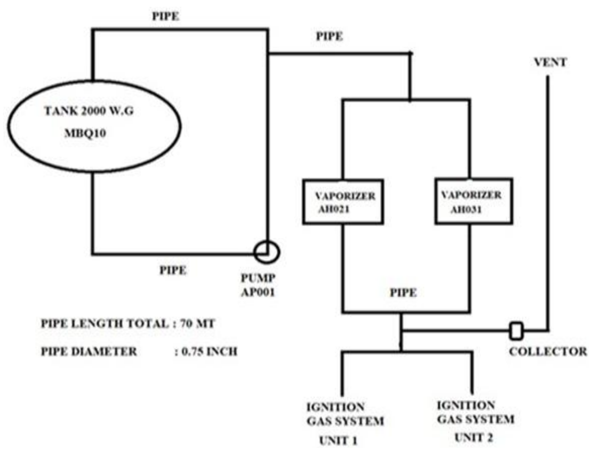

Figure 1. Ignition system.

The ignition gas system supplies the flow of ignition gas required for formation of ignition flames. Each burner is provided with an ignition gas burner and spark plug. The ignition gas system supplies the ignition gas burners with ignition gas at the proper time to produce the ignition flames. Vaporizers are utilized to increase the temperature of liquefied propane or butane, changing its phase from liquid to gas. These devices are engineered to handle substantial quantities of liquid petroleum gas and convert it into vaporized gas consistently, maintaining a steady flow rate and pressure ranging from hundreds to thousands of gallons per hour. When gas oil is used as main fuel, the ignition gas is taken from the propane tank. This storage tank has a capacity of 500 W.G., contains liquid gas in relation of 40% Propane 60% Butane. The pump has the task to transfer liquid gas from the tank to the vaporizers that transfer the required thermal input to the liquid gas in order to have it in gas phase. Regarding the protection of the Ignition system, it is necessary to mention that according to the design the system has equipment such as safety valves, pressure transmitters, etc. that perform the task of controlling the operation of the ignition system.

2.3. Hazard and Operability Analysis (HAZOP)

HAZOP is recognized as one of the most effective and rigorously structured techniques for identifying hazards in the chemical industrials. It is widely employed across process industries to pinpoint potential hazards and operational challenges. The widespread implementation of HAZOP across various fields underscores its reputation as a powerful technique for enhancing diverse systems (Marhavilas et al., 2019).

HAZOP is a very effective method for identifying process-related hazards and ensuring the implementation of effective control measures to protect systems or existing facilities. HAZOP study involves a systematic examination of a system, process, or operation with comprehensive design information, conducted by a multidisciplinary team. It is among the most extensively employed methods for identifying hazards in the chemical industries. This is achieved by employing a set of guidewords along with system parameters to identify significant deviations from the intended design. When a deviation is detected, the team assesses its consequences using their experience and judgment. If a cause can be identified for a deviation, the team then analyzes its effects or consequences. They assess whether existing protective systems or safeguards mitigate the risk to an acceptable level. If not, or if there's uncertainty in any part of the analysis, the team documents a recommendation for action, including a reference number, parameter, guideword, cause, and details of protective systems, Conversely, the HAZOP study can serve as a valuable tool to provide maintenance and inspection staff with a prioritized list of tasks and areas of focus (Crawley and Tyler,2015).

2.4. Decision Matrix Risk Assessment (DMRA)

Risk is determined by the probability of an event (such as a specific hazard occurring) and the potential consequences if that event does occur. Qualitative risk assessment (QRA) is a method employed to evaluate the risks associated with specific hazards. It is utilized for events that are uncertain and could potentially lead to significant consequences. Qualitative assessments are regarded as effective for evaluating relative levels when comparing or examining multiple alternatives, especially when precise data or estimates of outcomes are unavailable (Musyafa and Adiyagsa, 2012). Quantitative data on reliability is often unavailable for specific installations, leading to greater reliance on qualitative assessments. The risk assessment matrix is utilized to rank risks according to their type and probability of occurrence. This approach helps assign risk assessment values based on the severity of potential consequences and the likelihood of those consequences occurring. This classification value is often associated with various types of risks, guiding decision-makers to accurately understand the risk level.so employing an appropriate risk assessment tool helps in determining the necessary time and cost to mitigate risks to an acceptable level. The risk matrix is utilized for hazard classification and calculating the Risk Priority Number (RPN), represented by the following equation 1:

$$\text{RPN} = \text{Severity} * \text{Likelihood} \tag{1}$$

where, severity is seriousness of the most probable consequence of a particular hazard occurrence and likelihood is probability of the most likely consequence occurring in the event of a hazard occurrence.

The initial risk-ranking matrix incorporates severity rankings and frequency rankings to enable a qualitative assessment of the consequences associated with each hazard. This matrix facilitates the screening of each identified hazard, assigning rankings and recommending appropriate measures to eliminate or mitigate hazards that are ranked as high priority. Table 1 and Table 2 display the severity of consequences and the likelihood of events used to rank the hazards identified in the conducted HAZOP Study. Table 3 illustrates how the relationship between severity and likelihood rankings is utilized to assign risk rankings to each hazard. It also includes the definitions of risk ranks used in ranking the hazards identified in the HAZOP Study. Table 4 shows the criteria for prioritizing identified risks.

2.5. Areal Location of Hazardous Atmosphere (ALOHA)

ALOHA is a widely utilized hazard modeling program designed for chemical emergency planning and response. ALOHA enables users to input details regarding an actual or potential chemical release and subsequently generates threat zone estimates for various hazard types. The program can model toxic gas clouds, flammable gas clouds, Boiling Liquid Expanding Vapor Explosions (BLEVEs), jet fires, pool fires, and vapor cloud explosions. (EPA, 2016).

Table 1. Severity category

	Public	Worker	Property
A	Major release of AHM*	Loss of life	Major fire or explosion and/or loss of production
B	Moderate release of AHM	Severe injury or disability	Moderate fire or explosion and/or loss of production
C	Small release or AHM	Loss time injury but no disability	Small equipment damage or loss of production
D	Very small release of AHM with no significant impact	First aid injury but no disability	Minor equipment damage or minor loss of production
E	No hazard	Not a significant hazard	Not a significant hazard

*AHM: Acutely hazardous material

Table 2. Likelihood category

1	Likely	Occurrence as often as once in an operating year in any similar plant
2	May occur	Frequency between once a year and once in 10 operating years or at least once in 10 similar plants operated for 1 year
3	Not likely	Frequency between once in 10 years and once in 30 operating years or at least once in 30 similar plants operated for 1 year
4	Very unlikely	Frequency of less than once in 30 year or less than once a year in 30 similar plants operated for 1 year
5	Not probable	Not probable

Table 3. Risk Ranking matrix

	1	2	3	4	5
A	1	1	2	3	NP
B	1	2	3	4	NP
C	2	3	4	4	NP
D	4	4	4	4	NP
E	NH	NH	NH	NH	NH

NH= No hazard, NP= Not probable

Depending on the scenario, different results can be obtained by selecting three different sources of leakage or explosion, direct, tank or pipe. The contact of the leak with a source of fire is present in the selection system. This situation makes the possible results of the scenario more realistic. The domains resulting from the scenario can interact with the area where the event occurred by using google earth or MARPLOT programs. In this study, as a result of the HAZOP analysis, the hazard that could cause explosion was selected as “possible excessive temperature in the vaporizer and possible vaporizer breakage leading to fire/ explosion”, and the explosion modelled with Aloha for this deviation.

Table 4. Risk decision criteria

	Risk Rank	Recommendation
1	Unacceptable	Should be mitigated to risk rank 3 or lower as soon as possible
2	Undesirable	Should be mitigated to risk rank 3 or lower within reasonable period
3	Acceptable with Controls	Verify that procedures, controls, and safeguards are in place
4	Acceptable as is	No action is necessary

The assumptions taken into account during the study, the state of contact with the emission type fire source and the state of not having been taken into consideration. While the possible scenario as a result of contact with the fire source is divided into three groups (toxic area, flammable area and explosion area), only toxic dispersion modeling has been performed in the absence of contact with the fire source. In each scenario, constant wind speed and prevailing wind conditions were assumed. Gas compositions observed for each unit were based on their specific process conditions. However, the report only accounted for propane gas due to the gas detector's capability of detecting propane gas specifically, rather than mixed gases.

3. Results

3.1. DMRA and HAZOP Results

Table 5 illustrates the number of identified risks associated with the ignition system used in the operation of gas turbines and generators within the gas power plant. As shown in Table.5, 13 hazard has identified from different deviations in level, temperature, pressure and flow. Two of the risks were in unacceptable zone that means should be mitigated to acceptable risk zone as soon as possible. Three of the identified risks were in undesirable zone and should be mitigated to acceptable or lower within reasonable period. Four of the risks are identified in green zone that mean they are acceptable with controls. Four risks in rank are acceptable according the organization risk matrix. After assessment the identified risk from HAZOP study, the significant risk with important consequences had chosen. According to the findings we can note that the most critical risks were presented by the formation of high and low temperature. High temperature may result **in** possible over-temperature in vaporizer, possible rupture of vaporizer and leading to fire or explosion and if low temperature happen may lead to less ignition gas supplied to burners and delayed operation and failure of generator turbine (GT) startup that will cause loss of production.

Table 5. The number of identified risks

Deviation	No. of Hazards	Risk rank			
		1	2	3	4
Level	3		1	1	1
Temperature	2	2			
Pressure	2		2		
Flow	6			3	3
Total	13	2	3	4	4

The undesirable risks were presented by failure in hardware because of failure of pressure regulator during operation and Lower/ No Level in result of level indicator failure on tank. This risk may occur during maintenance and inspection activities. For these scenarios, protection and preventive measures are recommended, as detailed in Table 6.

Table 6. Final result of HAZOP study

Deviation		Cause	Consequences	S	Safeguard	L	R
1	Hardware Failure	Failure of pressure regulator during operation	Hot compressed air into pressure regulator. Possible Personnel injury due to hot surface. Increased temperature of solenoid valve above the design value	B	Operator inspection. Operator training and procedure.	2	2
2	Hardware Failure	Failure of pressure regulator during operation	Leakage of gas to compressor and combustion chamber. Potential fire/explosion	B	Operator inspection. Operator training and procedure.	2	2
3	Higher Temperature	Control system of vaporizer burner failure	Possible over-temperature in vaporizer possible rupture of vaporizer leading to fire / explosion	B	Operator inspection	2	1
4	Lower Temperature	Direct fire in vaporizer failure	Less ignition gas supplied to burners. Delayed operation. Failure of GT startup. Loss of production	B	Operator training and education. Flame monitors on burners (UV)	1	1
5	Lower/ No Level	LI on tank failure	No supply of fuel oil to GT units Possible GT fails to start	B	Flame indicator Operator standby	2	2

3.2. ALOHA Results

Simulation and analysis of possible accident results were made using ALOHA® version 5.4.7. ALOHA.

The study was conducted for a power plant located in Mashhad, Iran. The power plant is of the unsheltered double stored type. The fuel mixture used in the power plant is 40/70 propane/butane. According to the results of HAZOP and DMRA, the most important deviation is simulated by ALOHA. The scenario is modelled based on failure of zone control system in vaporizer burner, which is explained in Table 6 as deviation number three. Explosion caused by the propane/butane mixture delivered through the pipes are not simulated. Since the ALOHA program just able to simulate single chemical compound scenario, the analysis should be performed for propane. Chemical values of propane with Cas number 74-98-6 and molecular weight 44.10 g/mol and site information are given in Table 7.

Table 7. Site information and chemical data

Location	Mashhad, Iran
Building Air Exchanges Per Hour	2.03 (unsheltered double storied)
Time	May 15, 2021 13:56 hours ST (using computer's clock)
Chemical Name	Propane
CAS Number	74-98-6
Molecular Weight	44.10 g/mol
AEGL-1 (60 min)	5500 ppm
AEGL-2 (60 min)	17000 ppm
AEGL-3 (60 min)	33000 ppm
IDLH	2100 ppm
LEL	21000 ppm
UEL	95000 ppm
Ambient Boiling Point:	-44.7° C
Wind	21 meters/second from SE at 10 meters
Ground Roughness	open country
Air Temperature	29° C
Cloud Cover	5 tenths
Stability Class	D
Inversion	No Inversion
Relative Humidity	22%

ALOHA requires information about the prevailing weather conditions under which the simulation will be conducted. Therefore, the weather conditions entered the simulation are briefly as follows: wind speed is 21 m/sec blowing from the south-west direction. The ambient temperature is 29oC, there is no inversion, the humidity is 22% and the stability class is D. The lower explosive limit of Propane, which is predefined in the ALOHA, is 21000 ppm and the upper explosion limit is 95000 ppm. The defined scenario and results are described as follows: Propane is in gas form at the specified values and all the gas transmitted in the pipes was simulated by considering it as propane. The amount of radiation emitted by the burning gas is shown in Figure 2a. While the effective distance of the radiation was lethal for living creatures at 50 meters in the direction of the wind, it was observed that the radiation level decreased as the distance increased and disappeared at 90 meters.

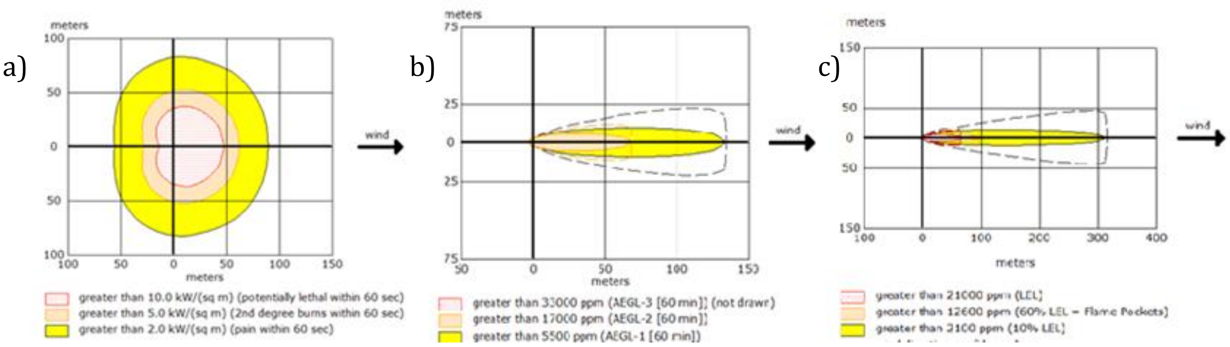

Figure 2. a) Thermal radiation threat, b) Toxic area, c) Flammable area.

The potential danger from not burning the gas coming out of the pipeline can result in three situations as toxic area vapor cloud, flammable area vapor cloud, blast area vapor cloud as shown in Figure 2b and Figure 2c. If the gas escaping from the pipeline connected to the evaporator does not come into contact with an igniter source, the gas cloud is toxic. The effective range of the toxic vapor cloud is observed that the toxicity in the environment reaches 33000 ppm, it exceeds the distance of 50 meters in the first 60 minutes, and the toxicity decreases as the distance increases, and there is no toxic cloud effect at a distance of 150 meters. Flammable areas may occur even if the concentration is below the lower flammability level (LEL). At 21,000 ppm, where the Lower Explosive Limit (LEL) is at its peak, the flammability is also at its highest. The explosion caused by the combustion of flammable vapor or gas generates considerable overpressure. Therefore, contact with the fire source at 100 meters will cause vapor cloud explosion and the impact area will reach the highest level. This domain is shown in Figure 3a. While structures within an area of approximately 70m are damaged by a pressure above 3.5 psi, it results in serious injuries to people. The blast area is displayed on Google Earth in Figure 3b.

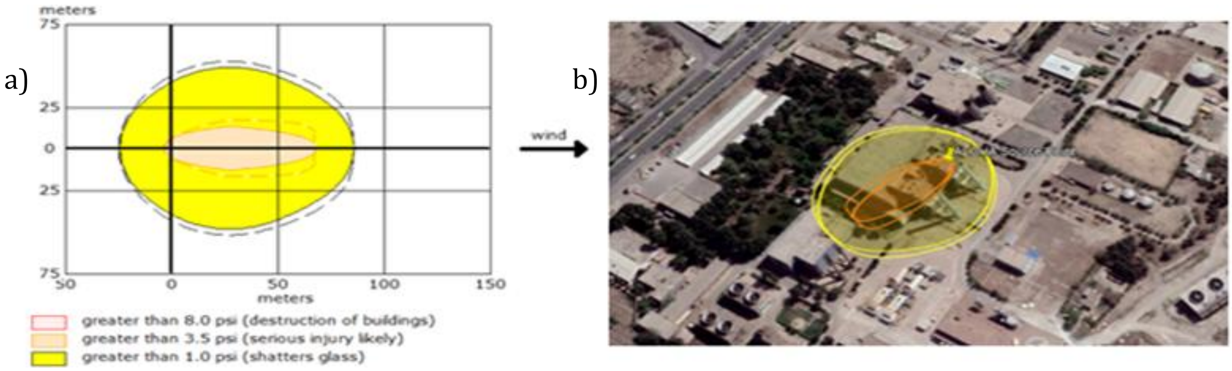

Figure 3. a) Thermal radiation threat, b) Blast area from Google earth view.

4. Discussion

(Sánchez Colmenarejo et al., 2022) mentioned that recognizing hazards and assessing risks are crucial elements in ensuring the safety of industries including power plants. Their research presents a unique risk analysis approach that enhances safety during commissioning and start-up operations and also provides an overview of the processes and procedures involved in power plant construction, in comparison to those used in other industrial sectors. A systematic review of the scientific literature was conducted to understand the current state of risk assessment and hazard identification methods used in power plant construction projects. The results indicate that HAZOP is a commonly used method for identifying hazards and risks in power plants and it highlights how a major disruption occurred in the past 15 years, following the widespread implementation of the HAZOP technique during project execution. Over the past 20 years, more than 2,500 articles have referenced HAZOP analyses, establishing it as the most widely used PHA methodology and a cornerstone of process safety and management programs (Hoorelbeke, 2021). Ensuring safety is a key priority in the chemical industry, (Mocellin et al., 2022) stated that HAZOP explores the consequences of deviations from design conditions and enables researchers to thoroughly understand the nature and scope of potential hazards in research activities and experiments, ultimately helping to reduce risks to an acceptable level.

The study by (Penelas and Pires, 2021) demonstrated the effectiveness of the HAZOP methodology in identifying potential hazards and assessing the risks associated with equipment malfunctions and property damage. It highlighted HAZOP as a valuable tool for evaluating impacts on both new and existing process facilities while providing crucial insights for company leaders, decision-makers, and operations managers. They implemented the HAZOP methodology in process and safety operations within the oil production industry. By dividing a crude oil production unit into smaller sections for analysis, they identified 71 potential risks.

The analysis of 242 tank accidents in industrial facilities over the past four decades revealed that fire emerged as the predominant cause of loss, with 145 occurrences. Furthermore, explosion was identified as the second most common type of loss, with 61 reported incidents. Collectively, fire and explosion constituted the majority, encompassing 85% of the total cases (Chang and Lin, 2006). Alsaffar and Ezzat (2020) investigated operational risks in combined cycle power plants using hazard identification techniques. The study focused on potential risks associated with the normal operation of boilers, gas and steam turbines, generator systems, and gas inventory systems in a typical combined cycle power plant. The findings revealed that the most probable consequences of the identified hazards and risks are fire and explosion.

Given that the most significant consequences of risks associated with large industries are fires and explosions, this study specifically concentrates on these hazards.

(Ahmad et al., 2016) conducted an investigation into work-related accidents at power plants using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) process. Data were collected from two coal-fired power plants in Malaysia. The study identified five hazards at the power plants, none of which were classified as high risk. However, the root cause of all the identified hazards was attributed to human factors. The conducted study explicitly highlights the significant role of the human factor in the occurrence of accidents.

(Kumar and Bhattacharya, 2015), using a method similar to ours, conducted a HAZOP study for a vaporizer in an ammonia storage yard and proposed modifications for automating the water supply to the vaporizer. They considered different release scenarios for both vapor and liquid leaks based on various orientations of the storage bullet, simulating hazardous chemical releases using ALOHA and PHAST software.

(Iskender, 2020) conducted a study to identify the hazards associated with a stainless-steel spherical tank containing pure acetone. The study applied HAZOP to identify potential hazards and used ALOHA to simulate the consequences as well.

(Ilic et al., 2018) analyzed the environmental and human health impacts of a chlorine gas leak, modeling the release of 3.373 tons of chlorine gas over one hour using ALOHA software. (Rodrigues et al., 2017) used ALOHA software simulations to identify and quantify the potential physical effects and explosion damages in three routes of the diesel hydro-treatment unit at the Abreu e Lima Refinery. The application of ALOHA not only aids in identifying risks within the refining process but also facilitates process management and enhances control over critical areas requiring heightened safety measures.

(Hung et al., 2024) emphasized the critical importance of ensuring firefighter safety during oil tank fires, given the considerable risks associated with thermal radiation. Their research employed the Fire Dynamics Simulator (FDS) and ALOHA software to model a severe oil tank fire scenario at the Zhushan Branch Power Plant, which houses two heavy oil tanks and several light oil tanks. The study highlights the significance of integrating FDS and ALOHA outputs to devise a balanced and adaptive strategy for firefighter safety, thereby optimizing response protocols in high-risk environments. The findings offer crucial insights for defining safety zones, enhancing fire protection and emergency response standards, and informing strategy development for large-scale oil and petrochemical storage facilities.

5. Conclusion

Power plants play a crucial role in generating the energy that supports societies. Prioritizing safety measures in power plants is essential to ensure the welfare of workers, reduce the occurrence of accidents, and mitigate environmental consequences.

Considered as a whole, most of the previous HAZOP studies were focused on chemical process and the studied-on power plant almost focused on identify fuel tanks hazards, hence, this study attempts to identify the specific hazard related to ignition system of power plant as an important part of operation. Accidents in this area have the potential to cause multiple injuries and fatalities both on-site and off-site, as well as significant damage to assets and long-term production losses.

This study used two techniques to evaluate and assess ignition system hazards in a gas power plant located in northern Iran. The HAZOP technique was employed to identify hazard scenarios that could lead to fire or explosion accidents, pinpointing their causes, locations, and recommended protective measures. A risk matrix was utilized to prioritize the identified risks. Additionally, to provide a clearer understanding of the severity of hazards, ALOHA software was employed to model, simulate, and predict the effects of fire and explosion hazards.

This modeling provides a visualization of the fire and explosion risks, facilitating safety decisions that are crucial for their mitigation. The findings from this study enabled us to propose control and preventive measures aimed at reducing and mitigating fire and explosion accidents.

Based on the findings, the ignition system fueled by gas presents a significant risk of fire and explosion.

The most significant identified risk is the failure of the vaporizer burner's control system due to temperature deviations. Installing a temperature indicator on the vaporizer outlet line can assist operators and supervisors in detecting and preventing such deviations and their potential consequences. Based on the simulation results, the explosion and radiation effects, along with the potential domino effect, pose significant risks that could lead to fatal consequences for human life.

Moreover, in the case of lower temperature deviation, installation of temperature indicator in vaporizer outlet line, provide electrical heat tracing and insulation on the pipeline from vaporizer to pressure regulator vale and provide vent line after pressure regulator valve will help to reduce the failure rate.

The inability of the ALOHA program to produce a result analysis for situations that may occur in cases where the chemical transmitted in the pipes is in liquid form, and this risk situation can be taken into account by using alternative programs such as PHAST or SAFETI computer modelling programs. In addition, the calculation of the mixture conveyed to the vaporizers by pipe will increase the reliability of the possible results.

Considering the high-risk operating conditions, combining the Fault Tree Analysis (FTA) and Event Tree Analysis (ETA) methods could enhance risk identification and lead to more accurate results in future studies.

The primary objectives of the study are to prioritize human safety, followed by the protection of the environment and facilities, while minimizing financial losses within the power plant under examination.

According to the study findings the importance of personnel's role as an important safeguard has cleared. Based on evidence, workers' behaviors influenced by safety training, processes, and programs have been recognized as significant factors contributing to job site accidents in recent years (Shine et al., 2015). So, it’s necessary to enhance safety awareness among all workers. Training is of utmost importance in the realm of fire safety. It is imperative that employees working in power plants undergo thorough fire safety instruction, encompassing areas such as the prevention of fires, identification of potential fire hazards, correct utilization of fire extinguishers, and protocols for evacuations. By implementing comprehensive safety measures, conducting regular inspections, fostering a strong safety culture, prioritizing safety for a sustainable future, and providing ongoing training, power facilities can reduce incidents, protect employees, and ensure a reliable energy production.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	N.S.	M.E.O.
C	80	20
D	70	30
S	40	60
DCP	80	20
DAI	70	30
L	90	10
W	80	20
CR	50	50
SR	80	20
PM	80	20
FA	90	10

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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