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HAZOP Study and Layer of Protection Analysis Based Fuzzy System at Oil Distribution Unit, Surabaya- East Java

Ali Musyafa[1,*] , Revina S. K. Pradana[2], Imam Abadi[3],Bambang Lelono Widjiantoro[4]

[1] Department of Engineering Phisics, Faculty of Industrial Technology
Kampus ITS, Jl.A.R. Hakim, Surabaya – Indonesia, 60111

[2] Department of Engineering Physics, Faculty of Industrial Technology
Kampus ITS, Jl.A.R. Hakim, Surabaya – Indonesia, 60111

[3]Department of Engineering Physics, Faculty of Industrial Technology
Kampus ITS, Jl.A.R. Hakim, Surabaya – Indonesia, 60111

4Department of Engineering Physics, Faculty of Industrial Technology
Kampus ITS, Jl.A.R. Hakim, Surabaya – Indonesia, 60111

Corresponding author's email: musyafa [AT] ep.its.ac.id

ABSTRACT— *The oil industry has an important role in sustaining community life. Green environment and zero accident will affect the environmental balance and sustainable development. The balance of the built environment to maintain the fuel supply system so it does not paralyze the transport system and community activities. It is closely related to the operational activities in the process of distribution of fuel oil (BBM) from the tanker to the charging on cars where the oil distribution impacts of high risk such as fire, explosion, leakage, and oil spills. Risk identification is done based LOP (Layer of Protection Analysis) A to display the value (SIL) Safety Integrity Level on several scenarios. SIL calculation encourages economic impact analysis based on modern software. Fuzzy systems are applied in the risk assessment on the fuel distribution system with multiple inputs that are reviewed from several aspects to produce output that is easily understood and reliable. (FLOPA) Fuzzy Layer of Protection Analysis appropriately used as expert-based risk assessment methods that show layers of protection are qualitatively and quantitatively. Rule base-based expert system used in FLOPA. The linkage between risk impacts on the level of Safety Integrity Level is known as a firm step in preventing environmental pollution. Probability economic impact FLOPA system used by management for decision making big impact on the economic resilience of the company and the needs of society. Evaluation is the guarantor of systems, assets, environment, and safe reputation for companies and governments for the creation of sustainable development so that environmental and green city as well as the economic sector to be smooth. This is evidenced by the rating node SIL 1 to 3, i.e. NO SIL, SIL 0, and SIL 1. In addition the results FLOPA economic impact on node 2 to 3 overall medium categories with total losses / year in the range of US $ 10,000 - US $ 100,000.*

Keywords— Hazop, fuel distribution, risk assessment, SIL, FLOPA.

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1. INTRODUCTION

Sector of the oil industry is a sector that has the potential hazards and high risks. Each company also has an obligation to maintain the environmental aspects. Overview of the operation needs to be done in terms of the process of assessment of the impact of a security risk, the economic environment as well as qualitatively and quantitatively. This step is necessary to reduce the potential and a high risk of fire, explosion, leakage, and oil spills. The distribution process is one important aspect that needs to be maintained accuracy and precision in order to provide the best service to consumers. Product distribution channels of fuel from the tanker to the distribution tank truck has the chance of losses and high potential hazards associated with some aspects such as human, assets, reputation, and the environment. This is the underlying risk impact study done to see deviations thus calculated risk in terms of frequency can be done with a simple method Layer of Protection Analysis (LOPA). LOPA used as a risk assessment indicates protection layer qualitatively and quantitatively in making scenario imminent danger. (Kenneth First, 2010).

In general, the oil and gas industry has a security system in the form of safety instrumented system (SIS) that can reduce the impact that occurred at the time of danger and system failures. With the safety system will have an impact on the environment, assets, and the good reputation of the company. Zero accident would establish a balanced environment and fuel supply system runs well. Operating system distribution that is well maintained can facilitate the transportation system and community activities. This resulted in the creation of good development in terms of a safe environment from hazards as well as the city that has smooth economic conditions.

Modern software-based decision-making is needed to provide a better assessment in its application to models of effective and reliable. Fuzzy system is one method that is appropriate for use in an assessment, estimates and predictions qualitatively and quantitatively. Fuzzy system multilevel (cascaded fuzzy) has been applied by using a type of Mamdani in determining Safety Integrity Level (SIL) with a wide choice in the majority of drafting safeguard danger scenario. (Khalil, Abdou, et al, 2012). (FLOPA) Fuzzy Layer of Protection Analysis is an expert-based risk assessment methods used to demonstrate proper protection layer qualitatively and quantitatively. With the FLOPA storey, assets, environment and safe system can be guaranteed to achieve sustainable development and economic impact lancer. Based on the experience of the experts, the system adopted to deal with the uncertainty of existing data so that the output can be used for the evaluation of a particular case. (Guozhong, Neng Zhu, et al, 2011). Type Takagi Sugeno fuzzy multilevel system proposed to improve outcome and facilitate the processing of the data so that the output of linguistics can be understood by any party as well as facilitate the management in decision making.

2. MATERIAL AND METHOD

2.1 *Procedure of implemented LOPA*

LOPA worksheet, done by the highest deviation HAZOP, where the results of an impact event HAZOP consequence LOPA description. Severity HAZOP an impact event severity level Possible causes LOPA while HAZOP used to fill in the initiating causes LOPA. (Dowell, 1998). Severity HAZOP red or high risk category that can be integrated in LOPA. (Lassen, CA, 2008). Frequency for PFD calculations starting from the column initiating cause frequency obtained from the likelihood HAZOP. Protection Layers in LOPA obtained under the safeguard HAZOP which is described in several fields such as general process design, Basic Process Control System (BPCS), Alarms, and additional mitigation. The whole column is filled with IPL PFD value of each of the existing scenario.

2.2.1 Layers of Protection

General process design is generally considered to be inherently safer with nonzero PFD on the equipment and processes that are closely related to the failure of the industry. Professional adjustment is used for PFD on the operating conditions of the system being run. In certain cases may be decided that the desired design companies have a failure once in a hundred years so the value of 0.01. Basic Process Control System (BPCS) is used as the IPL to evaluate the effectiveness of access control and security systems in the event of human error. 3 safety functions that can be used as IPLs include continuous control action, the state controller (logic solver or alarm trip units or control relays). The value of the average PFD failure BPCS 0.1 which according to the recommended maximum limits IEC 61 511 which is attached to the Data Center for Chemical Process Safety (CCPS) in 2001.

Alarm is a second level of protection during normal operation to be activated by the BPCS were also the particular case there is intervention from the operator therein. PFD value of the response to the alarm is 1 if there are no alarm installation whereas if it is affected by the failure of the operator is 0.1 with routine work in once a month and workmanship routine procedure, assuming the well trained, no stress and fatigue) (CCPS 2001). Additional Mitigation Layer generally mechanical, structural or procedure of which may prevent or guard against hazards incident early. Based on IEC standards, the value PFD includes conditional modifier such as probability of fatal injury (Peter), probability of personal in the affected area (Pp), and the probability of ignatation (Pi). Value probability of fatal injury (Peter) of the process continue operating while the system is one that is not always operated (loading and unloading, batch processes and others) adjusted to the time when the process in the operation mode with the danger of total time that can be formulated as follows:

$$P_{tr} = \frac{time\ at\ risk}{total\ time} \qquad (2.1.)$$

P_{tr} is valid only if a failure occurs outside the hours of operation and repairs before operating time. Probability of personal value in the affected area (Pp) related to the time of the personnel is in place with the danger of total time that can be defined by the following equation:

$$P_p = \frac{time\ present\ to\ hazards}{total\ time} \qquad (2.2)$$

Pp value becomes 1 when danger occurs only in start-up and personnel are always there when these conditions. Value probability of ignatation (Pi) referring to the HSL / 2005/50 with the approach of the company on the following conditions:

a. Probability of ignatation (Pi) from disposal of liquid / crude = 0.01
b. Probability of ignatation (Pi) from the release of gas / condensate which are small = 0.1
c. Probability of ignatation (Pi) from the release of gas / Condensate were a large number = 0.5
d. Probability of ignatation (Pi) in case of rupture or Explosion = 1.

Intermediate Event Likelihood (IEL) is the product of the initiating cause likelihood (ICL), probability of failure on demand (PFD) of the Independent Protection Layer (IPL) and frequency conditional modifiers formulated as follows:

$$\mathrm{IEL} = \mathrm{ICL}\, x\mathrm{PFD}_1\, x\mathrm{PFD}_2 x \ldots \ldots \ldots x\mathrm{PFD}_n\ x\ P_p\ xP_i\ xP_{tr} \quad (2.3.)$$

2.2.2 Safety Integrity Level (SIL)

SIL value indicates the probability of failure category SIF which ensure Initiating Event Likelihood (IEL) does not exceed the target mitigated Event Likelihood (TMEL) with some provisions as follows:

a. If the number of IELT ≤ TMEL, the risk reduction is not necessary because it does not exceed LOPA ratio> 1 with the following formula:

$$\text{Rasio LOPA} = \frac{\text{TMEL}}{\text{IELt}} \quad (2.4.)$$

b. If the number of IELT> TMEL and there SIF,   of the SIF.

c. If the number of IELT> TMEL and there are no SIF, the existing layers are considered in adequate for risk mitigation so that the necessary recommendation for a strategy inherently safer design or redesign of the system, adding a protective layer / SIF.

SIL is determined by the safety rules of IEC 61508 and adapted to industrial process in which the 61 511 existing levels required for risk reduction.

Table 2.1 Integrity Level for SIF

SIL categories	PFD SIF	RRF= (1/PFD)
NR- not requirement	$1 \leq \mathrm{PFD}$	RRF≤1
SIL 0	$10^{-1} \leq \mathrm{PFD} < 1$	$1 < \mathrm{RRF} \leq 10^{1}$
SIL 1	$10^{-2} \leq \mathrm{PFD} < 10^{-1}$	$10^{1} < \mathrm{RRF} \leq 10^{2}$
SIL 2	$10^{-3} \leq \mathrm{PFD} < 10^{-2}$	$10^{2} < \mathrm{RRF} \leq 10^{3}$
SIL 3	$10^{-4} \leq \mathrm{PFD} < 10^{-3}$	$10^{3} < \mathrm{RRF} \leq 10^{4}$
SIL 4	$10^{-5} \leq \mathrm{PFD} < 10^{-4}$	$10^{4} < \mathrm{RRF} \leq 10^{5}$

Source: ISA TR 84.00.02-2002

2.3 FUZZY - LOPA

The data are also processed by the software-based fuzzy system. The system was built in several stages so as to have the output in the form of risk impact, SIL rating, the economic effects and risk decision. The block diagram can be seen in Figure 2.1.

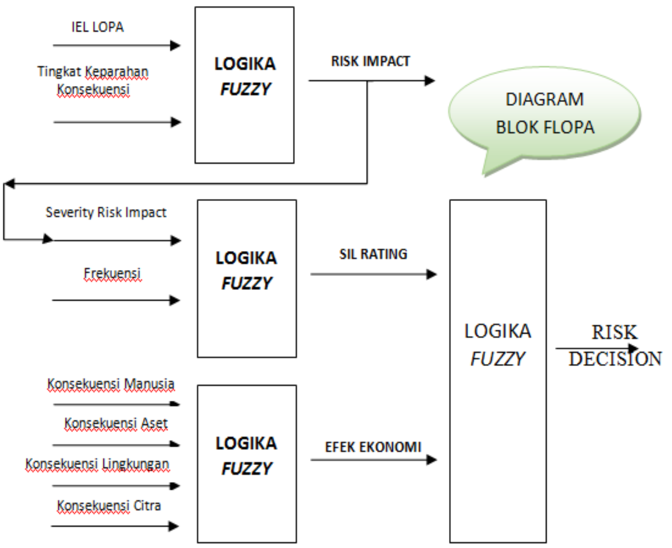

Figure 2.1 Diagram Blok FLOPA

The block diagram illustrates the stages of assessment where a rule uses the base so that the resulting output has a high accuracy. The output of the membership function is divided into three ratings are Low, Medium, and High. SIL assessment system based on fuzzy done by looking at the data input of severity and frequency so that the output is generated in the form of SIL as a standard safety levels. Economic impact assessment performed independently which does not depend on the output of other fuzzy system. Input of the consequences in terms of human, assets, environment, and imagery. Output membership functions form the category of low, moderate, high, catastrophic. I.e. the final stages of risk assessment in terms of safety to the economic impact that the output produced in the form of total risk for the management for decision making. Rule base used shown in Table 2.2.

Table 2.2 Rule base Risk Decision

Safety	Economical Effect			
	Low	Moderate	High	Catastrophic
Low	Low	Medium	High	Catastrophic
Moderate	Medium	Medium	High	Catastrophic
High	High	High	High	Catastrophic
Catastrophic	Catastrophic	Catastrophic	Catastrophic	Catastrophic

3. ANALISYS AND DISCUSION

3.1 LOPA – SIL RATING

System of risk assessment carried out in three nodes, namely the admission process (node 1), the process of accumulation (node 2), and distribution process (node 3). Node 1 includes tanker loading-pipeline-pig receivers, node 2 includes pig receiver-storage tank, node 3 includes storage tanks-pipeline-filling shed. Risks that commonly occur at node 1 in the form of leaking pipes and high pressure which can lead to flange / hose loose and cause an oil spill. Initiating causes in terms of instrument caused by MOV partially open and partially closed PCV where the PFD value derived from OREDA. Several other scenarios are caused by pressure and temperature fluctuations in discharge and oil viscosity so that pfd value on professional judgment and data CCPS at node 1, 2001. The system is equipped pressure indicator followed by operator action, density relay, and emergency shutdown valve.

At node 2 has a risk in the form of overpressure in the pipe leading to storage tanks rupture or defect as well as the potential for overfill the sump tank. Initiating causes in terms of instrument caused by a partially open MOV, error readings Level Indicator Transmitter or Automatic Tank Gauge pump failure, changes in temperature and pressure transmitters, breather valve and surge relief valve and pressure relief valve partially closed. Systems on this node has SIS is equipped with several instruments attached to the tank, such as a relay valve, pressure relief valve, and automatic ignatation to protect the risk of potentially explosive atmosphere in the tank. Data obtained from the PFD instrument OREDA, professional judgment, and CCPS.

Risks to the node 3 in the form in which the over fill caused by faulty instrument readings or human error. Impact event on node 3 in the form of hydrocarbon emission, oil spills on sump tank and changes in the distribution of feedstock. Some of this scenario with regard to initiating causes in the form of flow and level transmitter is not working properly, an error reading metering as well as damage to the tank car and the charging pump oil. PFD value derived from OREDA and professional adjustment. .Based on the analysis results obtained using LOPA SIL levels such as Table 3.1

Table 3.1 SIL Rating LOPA Node 1-3

Node 1 (Tanker Loading - Pipeline - Pig Receiver)	
SIL 0	66,67 %
SIL 1	33,33 %
Node 2 (Pig Receiver – Storage Tank)	
No SIL	27,27 %
SIL 0	54,55 %
SIL 1	18,18 %
Node 3 (Storage Tank – Pipeline – Filling Shed)	
No SIL	66,67 %
SIL 0	33,33 %

Table 3.1 is the result of the calculation of PFD Safety Integrity Function (SIF) of TMEL compared with the total value of Initiating Event Likelihood (IEL) in order to obtain some level of SIL on LOPA scenario node 1 to 3. Based on the SIL rating obtained seen that on each node requires IPL additions such as determination and installation of alarms based on the principle of ALARP (as Low as Reasonably Practicable) so as to reduce the risk of delay of the response that the operator must get off the field to address the specific hazards.

3.2 FLOPA – Risk Impact

Risk analysis performed gradually according to the fuzzy system based on the block diagram in Figure 2.1. The output looks on the surface like a picture viewer 3.1.

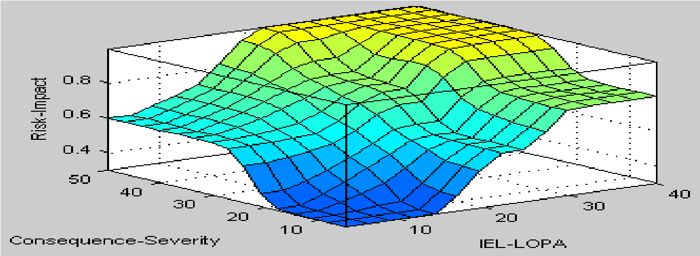

Figure 3.1 Surface Viewer Risk Impact

The output of the fuzzy system has the suitability of the risk assessment system on oil distribution companies in some cases. This may indicate that the results of the risk assessment based software have a level of validity that can be used to determine the steps to be taken management. Fuzzy assessment results show that one scenario has the risk by monitoring action at node 1 and node 2, 8 scenarios such as control measures and the 9 scenarios in the form of goals and objectives of the node 2 and node 3.

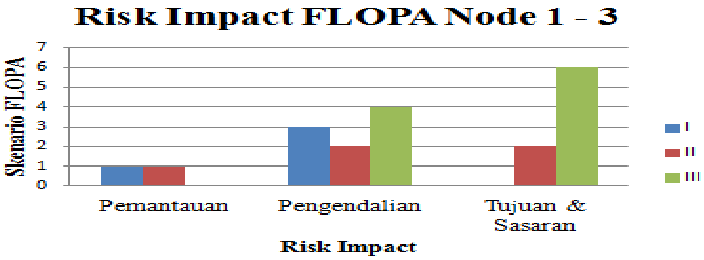

Figure 3.2 Risk Impact FLOPA Nodes 1-3

3.3 FLOPA – SIL Rating

SIL assessment based on fuzzy done after receiving the results of the risk impact FLOPA. The system has input from risk assessment impact and frequency so that the output of SIL levels. Results of surface viewer fuzzy system that was created by rule base shown in Figure 3.2. Overall levels of SIL on the scenario node 1 to 3 NR generate up to SIL 3 with the details shown in the graph 3.2.

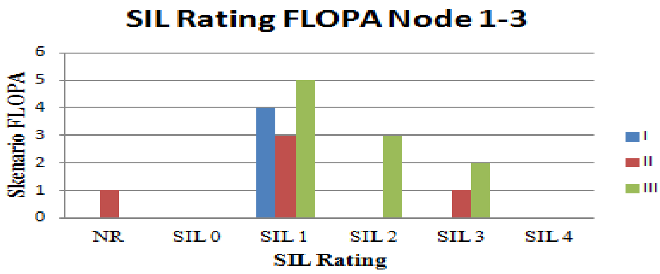

Figure 3.3 SIL Rating FLOPA Nodes 1-3

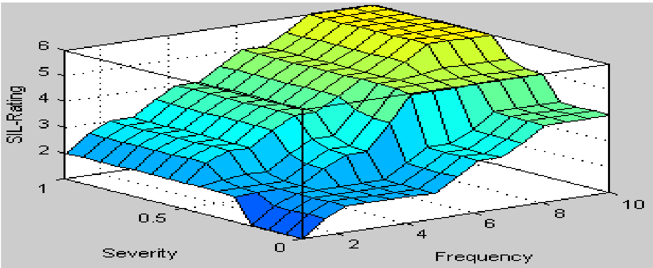

Figure 3.4 Surface Viewer SIL Rating

The figure indicated that the first node has a scenario with SIL level 1 so it does not indicate the need for a high level of security as the node 2 and node 3. At node 2 are the results showed SIL 3, it shows the need for more action in the scenario overflow tank along with the frequency often occurs. There are two scenarios in node 3 that has a level SIL 3 in which the impact occurs in the form of leaks, vapor emissions of HC, causing a potential fire. Results showed that the need for action to keep the risks that occur with a high frequency of occurrence.

3.4 FLOPA – Economical Effect

The effect of economic assessment is reviewed by four categories covering people, assets, environment, and reputation. Fuzzy system is built on 81 rule base so as to produce a 3-dimensional surface viewer with their respective terms of two coordinates. The output of the economical effect in the form of assessment results low, medium, high, and catastrophic. Results of the assessment of the node 1-3 fuzzy systems can be seen in chart 3.3

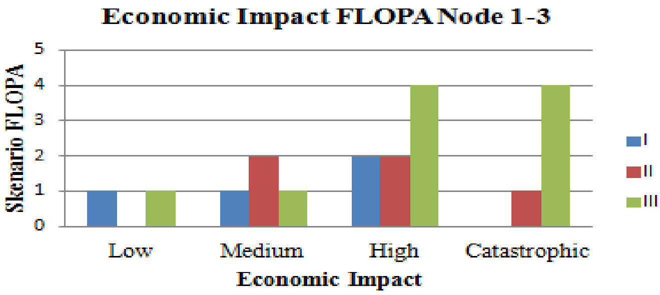

Figure 3.3 Economical Effect FLOPA Nodes 1-3

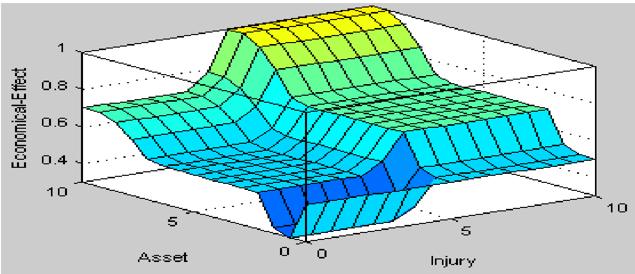

Figure 4.3 Surface Viewers Economical Effect

Figure 4.3 shows one picture of the link between the injury and the assets of the economic impact which the greatest influence on the asset tends to cause catastrophic economic impact. It has the distinction if a review of the terms of injury and the environment as well as the reputation which produce catastrophic with a balanced effect. Review of the aspects of environment and assets showed that the economic impact tends to be on a high state when it has a probability of above 0.5. This suggests that a good environment conditions and asset maintenance costs are high so the impact on the economic aspect of the company.

Unlike the case when viewed from the aspect of reputation and assets as well as the environment looks that good reputation to have economic impact tends to be high when compared with the review in terms of assets and the environment. This shows that in order to maintain the high reputation comparable with economic impact issued by the company. The influence of environment on the economic impacts tend medium, this is because the nominal issued to keep the environmental impact adapted to the existing employee action on the field, in accordance with the SOP so that companies do not need to pay is too expensive.

FLOPA decision shows the calculation of risk impact on several scenarios exist based on hazard identification data of the company, the management has calculated the fuel losses may cooperate with the relevant section in calculating the total risk scenario of the economic impact per year. Calculations can be performed using the following equation:

Probability of total risk x economic impact /loss event = Total impact /years .

By taking the results of calculations which have major risks that impact has been made on the scenario node 2 to node 3, it can be seen the relationship between the risk of losses impact the company as follows:
Total impact losses/year = 0.7 *S. 6,756,600,500, -The company suffered losses / year in the node 2-3 at IDR. 4,707,548,788, -
Results of the final risk arising from the scenario at node 1 to 3 can be converted to the severity based on CCPS 2008 and AS / NZS 4360: 2004 as well as the use of risk Metrics Company against the economic effects as follows:

a. Low: <US $ 1,000 - US $ 10,000
b. Medium: US $ 10,000 - US $ 100,000
c. High: US $ 100,000 - US $ 1 M
d. Catastrophic :> US $ 1 M

Loses / years node 2-3 on the scenarios that have been made show that the value of IDR. 4,707,548,788, -Medium category can be classified according to the risk matrix company, standard CCPS 2008 and AS / NZS 4360: 2004.

Results of impact FLOPA decision probability can be used to calculate the resulting impact / year adjusted to the existing scenario. Calculations can be performed on each scenario or scenarios in total as it has done in the calculation node 2-3 above. This can simplify the management in estimating the total risk associated with the impact loses company in accordance with the desired scenario.

3.5 LOPA-FLOPA

Base on Table 3.1 shows the results using the SIL calculation LOPA on each node that has been predetermined. NO SIL and SIL 0 on multiple nodes showed that the plant related still lack a layer of security protection on the system instrumentation. Lack of protective coating on the system offset by the participation of personnel to conduct regular inspections so that the level of security is still perceived by the company. SIL 1 on node 2 showed greater security protection for the tank operating at a higher risk such as overpressure and leaks that will have an impact on the economic sector. LOPA-based SIL calculation results are encouraging for economic impact analysis on multiple nodes based on fuzzy system. FLOPA provide an overview of the linkages 4 inputs such as human factors, assets, environment, and the reputation of the economic impact caused. Graph 3.2 shows the results of analysis FLOPA which gives the output in the form of categories of economic impact inflicted on several nodes, namely low, medium, high, and catastrophic. High and catastrophic economic impact can be validated by rule base that have been made based expert. This is what illustrates that FLOPA can be applied in ensuring sustainable development in order to build a green environment, the city that is safe, smooth and economic sectors.

4. CONCLUSION

LOPA have quantitative results in the form of risk analysis node SIL rating of 1 to 3, i.e. NO SIL amounting to 27.27% at node 1 and 66.67% in the third node; SIL 0 66.67% at node 1, 54.44% in the node 2, 33.33% in node 3, and SIL 1 amounted to 33.33% at node 1 and 18.18% in the second node

FLOPA produce the output of SIL 1 to 4 scenarios at node 1, 1 scenario with SIL 3 and NR as well as three scenarios in the form of SIL 1 on node 2, and the node 3 by 5 scenarios with SIL 1,SIL 2,3 scenarios form, and two scenarios with SIL 3 on node 3.

Decision impact on the scenario node 1 to 3 provide outputs that affect the safety and economic aspects of the company with several factors such as people, assets, reputation, and the environment.

Decision FLOPA produce the output of node 1 have low and medium impact with the first scenario as well as high impact with two scenarios, the node 2 has medium and high impact with two scenarios and the catastrophic impact with the first scenario, node 3 has a medium impact with the first scenario, high impact with 5 scenarios, and four scenarios resulted in catastrophic impact. Results FLOPA economic impact on node 2 to 3 overall medium categories with total losses / year in the range of USD. 10,000 - USD. 100,000

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REFERENSCE

[1] A. Manual Book. (2016), PT. Petrokimia Gresik. Ammonia Plan I.
[2] ANSI/ISA-TR84.02. 2002. Safety Instrumented Functions (SIF) –Safety Integrity Level (SIL) EvaluationTechniques Part 1: Introduction. Research Triangle Park, NC: American National Standard Institute.
[3] ANSI/ISA-TR84.00.02-2002 Part 3. Safety Instrumented Function (SIF) - Safety Integrity Level (SIL) Evaluation Techniques Part 3: Determining the SIL of a SIF via Fault Tree Analysis. American National Standard Institute.
[4] CCPS (Center for Chemical Process Safety). (2009). Guidelines for Developing Quantitative Safety Risk Criteria, Appendix B. Survey of worldwide risk criteria Applications. New York, USA: AIChE.
[5] Dowell, A. M. (1998). Layer of protection Analysis for determining safety integrity Level. ISA Transaction,37,155e165.
[6] Freeman, R. (2007). Using layer of protection analysis to define safety integrity level requirements. Process Safety Progress, 26.

[7] First, Kenneth. (2010).Scenario identification and evaluation for layers of protection analysis. Journal of Loss Prevention in the Process Industries, 23, 705e718.

[8] Going Bill, 2000. Advanced Control Steam Superheat Temperature on a Utility Boiler. IEEE Research Journal Volume-3 Issue-2.

[9] Guidance on "as low as reasonably practicable" (ALARP) decisions in control of major accident hazards (COMAH). (2002). UK: Health and Safety Executive. Available at:http://www.hse.gov.uk

[10] IEC- 61882. 2001. Hazard and Operability Studies (Hasp Studies) – Application Guide. Geneva: International Electro technical Commission.

[11] John N. Dyer, Anya P. Raibagkar, Massimiliano Kolbe, and Ernesto Solano "Blast Damage Considerations for Horizontal Pressure Vessel and Potential for Domino Effects", the Italian Association of Chemical Engineering, Italy, 2012.

[12] Johnson, R. W. (2010). Beyond-compliance uses of HAZOP/LOPA studies. Journal of Loss Prevention in the Process Industries, 23(6), 727e733.

[13] Khalil,M, et.al.. (2011). A cascaded fuzzy-LOPA risk assessment model applied in natural gas industry. Journal of Loss Prevention in the Process Industries, 25, 877e882

[14] Lassen, C. A. (2008). Layer of Protection Analysis (LOPA) for Determination of Safety Integrity Level (SIL). The Norwegian University of science of Technology. Saroyan.

[15] Montgomery, Douglas C "Introduction to statistical Quality Control 6th Edition", United States of America. 2009.

[16] M. Marshal, Edward and W. Scarp, Eric, "Safety Integrity Level Selection." (United State of America: Research Triangle Park, NC: ISA., 2002.

[17] Musyafa, A. And Kristianingsih, L., "Risk Management and Safety System Assessment from Power Plant Steam Boiler in Power Systems Unit 5, Paiton Indonesia", Australian Journal of Basic and Applied Sciences, 7(11) Sep 2013, Pages: 349-356, 2013.

[18] Musyafa, A. And Zulfiana, Erna., "Risk Management and Hazard and Operability Study on Steam Turbine Power Plant Unit 5 in The Power Generation Paiton, East Java-Indonesia", Advances in Natural and Applied Sciences, 7(5) December 2013, Pages: 510-518, 2013.

[19] Mustafa, A. ,at.al., " Hazad And Operability Study and Analysis of Safety Integrity Level Case Study: Ammonia Refrigerant Compressor at Petrochemical Plant" Advances in Natural and Applied Sciences, 9(8) July 2015, Pages: 36-42, AENSI Journals, 2015.

[20] Mustafa, A., at.al. "Reliability and Maintainability Assessment of the Steam Turbine Instrumentation System for optimization Operational Availability System at Fertilizer Plant", Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 132-139, 2014.

[21]. Musyafa, A. et.al. "Evaluation of the Reliability and Prediction Maintenance on the Air Compressor System in Ammonia Plant PT. Petrokimia Gresik", Australian Journal of Basic and Applied Sciences, 9(11) May 2015, Pages: 853-862, 2015.

[22] Poulose, Smear Maria, and Madhu, G., "Hazop Study for Process Plants: A Generalized Approach", International Journal of Emerging Technology and Advanced Engineering, 2012

[23] Robert W. Johnson. "Beyond-compliance uses of HAZOP/LOPA studies". Science Direct. Pp. 727-733., 2010.

[24] Ronny D. Noriyati, et.al..." Reliability Assessment of Cooling Pump For Parts Inventory Planning in Power Plant System, Paiton-Indonesia". Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 140-146 AENSI ISSN: 1991-8178. Journal home page: www.ajbasweb.com, 2014.

[25] Ronny Dwi Noriyati, et.al. "HAZOP Study and Determination of Safety Integrity Level Using Fault Tree Analysis on Fuel Gas Superheat Burner of Ammonia Unit in Petrochemical Plant, East Java. Asian Journal of Applied Sciences (ISSN: 2321 – 0893). Volume 05 – Issue 02, April 2017

[26] Silvana R.Dacosta, at.al "Hazop Study and Fault Tree Analysis for Calculation Safety Integrity Level on Reactor-C.5-01, Oil Refinery Unit at Balikpapan-Indonesia, Asian Journal of Applied Sciences (ISSN: 2321 – 0893), Volume 05 – Issue 02, April 2017

[27] Silvana D. Costa. et. al. "Evaluation Safety Integrity Level Using Layer of Protection Analysis in Recycle Gas First Stage Cycle Compressor at PT. Pertamina Persero" **.,** Australian Journal of Basic and Applied Sciences, 9(20) June 2015, Pages: 154-163, 2015.

[281] Skrtic, Lana, "Hydrogen Sulfide, Oil and Gas, and People's Health", Energy and Resources Group University of California, Berkeley. 2006.

[29]. summers, Angela. "Safety Integrity Level: Do You Understand The Odds?" (Journal of Control Engineering, *SIS-TECH* solution, LLC, 2000.

[30]. The Norwegian oil industry association, OLF Recommended Guidelines for the application of IEC 61508 and IEC 61511 in the petroleum activities on the Norwegian Continental Shelf, No.: 070 Date effective: 1.0 2, .2001.