HAZOPS Study on Fuel Distribution System Based on ANFIS Layer of Protection Analysis in Surabaya Installation Group PT. Pertamina Tanjung Perak

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ABSTRACT
Fuel industry is a sector that has potential hazards and high risks. Risks in terms of operating processes should be known in order to measure the qualitative and quantitative impacts resulting from economic, worker safety and environmental impact. This is closely related to the operations of the fuel distribution process from the fuel tanker to distribution trucks. Fuel distribution has high risk impacts such as fire, leakage, explosion and fuel spills. LOPA (Layer of Protection Analysis) based on hazard identification was done to show the value of the SIL (Safety Integrity Level) in some scenarios. Risks calculation using LOPA technique is effective and realistic to be used for developing scenario in Hazard and Operability Study (HAZOPS). SIL calculations lead to economic impact analysis based on modern software that is easily understood and reliable. Adaptive Neuro Fuzzy Interface System (ANFIS) is appropriate to be used as an expert-based risk assessment methods that show layers of protection are qualitatively and quantitatively. ANFIS mechanism is combination of Fuzzy Interface System (FIS), which is described in the neural network architecture. Result of this evaluation can be used by management to influence decision making towards company’s economic or public needs. The proof shows that is rating node SIL 1 to 3, NO SIL, SIL 0 and SIL 1. In addition, result of ANFIS Layer of Protection Analysis for economic impact is categorized in overall medium with total losses/year in US $ 10.000 – US $ 100.000.

Keywords: Fuel distribution; HAZOPS; Layer of Protection Analysis (LOPA); Adaptive Neuro Fuzzy Interface System (ANFIS)

1. Introduction
Fuel has an important role in an activity especially as vehicle fuel. The need for fuel is produced by PT. Pertamina (Persero) where one of the activities and distribution of the fuel marketing conducted by PT. Pertamina unit marketing (UPms) V. Surabaya installation group (ISG) fuel is a terminal PT. Pertamina (Persero) whose activities received, accommodate fuel storage ISG on a tank, fuel stations and channels to using tank trucks distribution. During the fuel distribution always be maintained so as not to gas stations are losing money in terms of material and non material. ISG are committed to place a priority on the aspect of safety in the operating the process. It was because that every operational activities, both from tanker ship up to charging on an automobile distribution tank have the potential to the danger that high as oil leakage, the explosion, the oil spill and the environmental pollution.

A review of the perspective of the operation process need to research on security risk, the environment, health, economic as well as qualitative and quantitative approaches [1]. Risk assessment is an important part of a process to define a state of being process in the condition may tolerated or need of some protection to is not in the condition of danger [2]. This needs to be taken to reduce the potential of the emergence of danger linked to human, assets, the environment and reputation [3]. Layer of protection analysis (LOPA) is a simple method of risk assessment in showing a layer of protection in qualitative and quantitative in a screenwriter danger is going to happen [4].

A safety system should also be having a level safety integrity of the protection of existing or called also with the safety integrity level (SIL) which is security levels the range of an equipment based instrument [5] or value measuring performance of the tools that configure safety instrumented system (SIS) such as censorship, logic solver and an element of the final. The safety of integrity level (SIL) presented the size of the probability of
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component failure safety instrumented system (SIS) when there are the request of [5]. The result of risk assessment will be used manager and engineer to implemented the work of the process in decision-making [6]

The decision was not based on modern software used in industry. An effective, in an efficient and reliable assessment of the risks, we need and the result is good, easy to apply and accurate than conventional methods. The decision-making based on the use of software with fuzzy HSEE is a good decision [7]. The process of using the system, it can provide the risk analysis using FLOPA [8]. With fuzzy logic, the analysis also apply to LOPA in decision-making in the chemical industry [6]. The next is to analyze the risks with adaptive neuro fuzzy interface systems for the security system ANFIS HSEE [9]. The merger anfis is mechanism fuzzy interface system (FIS) described in architecture neural network from an analysis of [10] results yield HAZOPSS used in preparing scenario ANFIS constructed upon the scene and consequences. Exodus ANFIS and estimated are required so that the results they danger understandable by the workers having knowledge a layman in the field of safety .The application of a method of HAZOPSS and LOPA ANFIS based are required so that the resulting give the methodology that was so much better off qualitative and quantitative fuel in ISG on distribution.

2. Methods

2.1. LOPA Procedures

LOPA worksheet done based on the HAZOPS highest deviation where HAZOPS consequence result is LOPA impact event description. Severity HAZOPS is impact event severity level of LOPA while possible causes HAZOPS is used to fill initiating causes LOPA column [8]. Red severity HAZOPS or high risk category can be integrated in LOPA [10]. Calculation of PFD frequency starts from initiating causes frequency column obtained from the likelihood HAZOPS. Protection layer in LOPA is obtained under HAZOPS safeguard which is described in several columns such as general process design, Basic Process Control Systems (BPCS), Alarms, and additional mitigation. The whole IPL columns are filled with PFD value from each existing scenario.

General process design is generally considered to be inherently safer with nonzero PFD on the equipment and processes which are closely related to industry failure. Professional adjustment is used for PFD on the operating conditions of running system. In certain cases, it can be decided that the desired design by companies has a failure once in a hundred years so the value is 0.01. Basic Process Control System (BPCS) is used as the IPL to evaluate the effectiveness of access control and security systems when human errors occur. 3 safety functions which can be used as IPLs include continuous control action, state controller (logic solver or alarm trip units or control relays). The average value of PFD failure BPCS is 0.1 which according to the recommended maximum limits IEC 61 511 which is attached to Center for Chemical Process Safety (CCPS) 2001. Alarm is the second level of protection during normal operation to be activated by the BPCS while also in certain cases there is intervention from the operator. PFD value of the response to the alarm is 1 if there is not any alarm installation whereas if it is affected by the failure of the operator, the value is 0.1 with routine work in once a month and workmanship routine procedure, assuming it is well trained, no stress and fatigue (CCPS 2001). Additional Mitigation Layer is generally mechanical, structural or procedural which may prevent or guard against imminent hazards. Based on IEC standards, PFD value includes conditional modifier such as probability of fatal injury (Ptr), probability of personal in the affected area (Pp), and the probability of ignition (Pi). Probability value of fatal injury (Ptr) of operating continue process while the system is 1, while systems which is not always operated (loading and unloading, batch processes and others) adjusted to time when the process is in the danger operation mode of total time that can be formulated as follows:

$$P_r = \frac{\text{Time at risk}}{\text{Total time}}$$

(1)

Ptr only applied when failure occurs outside the operating time and maintenance before operating time.

Probability of personal in affected area (Pp) value related with the personnel presence in hazard with total time, thus can be formulated by following (2) equation:

$$P_p = \frac{\text{Time present to hazards}}{\text{Total time}}$$

(2)

Pp value becomes 1 when hazards occur at the start-up only and personnel always present in that condition.

Intermediate Event Likelihood (IEL) multiplication of initiating cause likelihood (ICL), probability failure on demand (PFD) from Independent Protection Layer (IPL) and frequency conditional modifiers, it can be formulated in equation (3) as follows:
2.2. Safety Integrity Level (SIL) Value

SIL value indicates probability failure of SIF (Safety Instrumented Function) where ensure Initiating Event Likelihood (IEL) does not exceed Target Mitigated Event Likelihood (TMEL) in some conditions as follows:

- If sum of \( IEL_t \leq TMEL \), risk reduction is not necessary because it does not exceed LOPA ratio \( \geq 1 \) by following formula:
  \[
  Rasio \ LOPA = \frac{TMEL}{IEL_t}
  \]

- If sum of \( IEL_t > TMEL \) and there is SIF, so PFD SIF must be calculated to determine SIL from SIF.
- If sum of \( IEL_t > TMEL \) and there is not any SIF, so the existing layers are considered insufficient to mitigate the risk, it needs recommendations for inherently safer design strategy or redesign system and add the addition of protective layer / SIF.

SIL is determined by the safety rules of IEC-61508 and adapted to industrial process whereby existing levels are required for risk reduction [9].

<table>
<thead>
<tr>
<th>SIL categories</th>
<th>PFD SIF</th>
<th>RRF= (1/PFD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR-unnecessary</td>
<td>1 \leq PFD</td>
<td>RRF \leq 1</td>
</tr>
<tr>
<td>SIL 0</td>
<td>( 10^{-1} \leq PFD &lt; 1 )</td>
<td>1 &lt; RRF \leq 10</td>
</tr>
<tr>
<td>SIL 1</td>
<td>( 10^{-2} \leq PFD &lt; 10^{-1} )</td>
<td>10 &lt; RRF \leq 100</td>
</tr>
<tr>
<td>SIL 2</td>
<td>( 10^{-3} \leq PFD &lt; 10^{-2} )</td>
<td>100 &lt; RRF \leq 1.000</td>
</tr>
<tr>
<td>SIL 3</td>
<td>( 10^{-4} \leq PFD &lt; 10^{-3} )</td>
<td>1.000 &lt; RRF \leq 10.000</td>
</tr>
<tr>
<td>SIL 4</td>
<td>( 10^{-5} \leq PFD &lt; 10^{-4} )</td>
<td>10.000 &lt; RRF \leq 100.000</td>
</tr>
</tbody>
</table>

Source: ISA TR 84.00.02, 2002

2.3. Adaptive Neuro Fuzzy Inference System (ANFIS)

There are two phases of ANFIS Layer of Protection Analysis, first is creating ANFIS-LOPA system to determine severity rate of hazards. The second phase is creating ANFIS-LOPA systems used to determine the major risks which may occur from potential hazard and SIL (Safety Integrity Level) value. Type of ANFIS used is in numerical input and the expected output of numerical and linguistic, so it uses Mamdani and Takagi Sugeno type which accordance to the existing data [9]. The first phase can be attributed to human aspect, environment, and asset. The first phase output will be used to process the data in second phase by adding variable input such as economic aspect, thus the final output can be used as recommendations for decision making related to management needs. To simplify the ANFIS-LOPA phase, it is described in the following block diagram.
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3. Result and Analysis
3.1. LOPA – SIL Rating

Risk assessment system is done in 3 nodes, they are admission process (node 1), accumulation process (node 2), and distribution process (node 3). Node 1 includes tanker loading-pipeline-pig receiver, node 2 includes pig receiver-storage tank, node 3 includes storage tank-pipeline-filling shed. Commonly risk occur at node 1 is leaking pipes and high pressure which can lead to flange / hose loose and cause oil spill. Initiating causes from instrumentation caused by the partially opened MOV and partially close d PCV where PFD value obtained from OREDA. Some other scenarios caused by pressure and temperature discharge as well as oil viscosity so that PFD value base on professional judgment and CCPS 2001 data. Node 1 system is equipped with pressure indicator, followed by operator action, densito relay, and emergency shutdown valve.

Node 2 has overpressure risk in pipe so it leads to rupture or defect of storage tank as well as potentially overfilled of sumptank. Initiating causes from instrumentation caused by partially opened MOV, error reading of Level Indicator Transmitter or Automatic Tank Gauge, pomp failure, changes of temperature and pressure transmitter, breather valve and surge relief valve also pressure relief valve which partially closed. System at this node has SIS which equipped with some instruments attach to the tank, such as relay valve, pressure relief valve, and automatic ignitation to protect potential explosion of tank. PFD data instrument obtained from OREDA, professional judgment and CCPS. Risk in node 3 is the overfill caused by error instrument readings or human error. Impact event in node 3 is hydrocarbon emission, oil spills on sumptank and changes in feedstock distribution. Some scenarios regard to initiating causes such as flow and level transmitter which do not work properly, error metering readings as well as tank car defect and charging pump oil. PFD value is derived from OREDA and professional adjustment.

Based on analysis result using LOPA, it is obtained SIL level result using conventional method as in table 2.

<table>
<thead>
<tr>
<th>Node 1 (Tanker Loading - Pipeline - Pig Receiver)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>33,33%</td>
</tr>
<tr>
<td>SIL 0</td>
<td>50%</td>
</tr>
<tr>
<td>SIL 1</td>
<td>16,67%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Node 2 (Pig Receiver – Storage Tank)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>54,55%</td>
</tr>
<tr>
<td>SIL 0</td>
<td>18,18%</td>
</tr>
<tr>
<td>SIL 1</td>
<td>27,27%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Node 3 (Storage Tank – Pipeline – Filling Shed)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>66,67%</td>
</tr>
<tr>
<td>SIL 0</td>
<td>33,33%</td>
</tr>
</tbody>
</table>
3.2. ANFIS Layer of Protection- Decision Impact

Final decision is influenced by economic aspect and safety which can contribute result as decision impact that can be used for decision making by companies. Decision impact result is showed in Picture 4.13

![Picture 2. Surface Viewer for Decision Impact](image)

![Picture 3. Decision Impact using ANFIS-LOPA for Node 1-3](image)

Decision results from node scenarios 1-3 can be used for companies’ decision making. Risk impact provides an overview of potential hazards which occur in several scenarios, it can be assessed in several categories such as low, medium, and high. This category indicates actions taken by company in keeping risk impact on node 1 to 3 such as monitoring, controlling, goals, and objectives. Company always works on risk prevention and hazards impact occur, it encourages the management to cooperate with related parties in maintaining security and environmental pollution arising from the operations of oil distribution system. By keeping the instrument system security level, company has worked on preventing the environmental pollution. Safety Integrity Level indicates level of security in existing system, so that by having a safe instrument system can reduce potential hazards and impacts occur such as reduce the leak risk, oil spills, and carbon emission which released to environment. Final result of risk impacts are proportional to economic impact caused by.

Based on assessment result of ANFIS –LOPA in node 1, it is obtained final risk with low level occurs in loading/unloading process when installation or removal the floating hose, while in sounding cargo process it creates final risk in medium level. Final risk with high level occurs when loading/unloading process of fuel on board and pumping process of fuel receipt. Level of final risk appeared is closely related to severity level and economic impact towards company. It occurs because the impact such leakage and hydrocarbon vapors emissions affect the money spent by company in handling such impacts so that the risk can be reduced.

Node 2 has some final risk in medium level, high, and catastrophic in certain scenarios. Medium level occurs when accumulation process on operational and drain storage tank. Risk posed as over pressure and oil spills influence the economic impact of company in medium level. The loss suffered by company is more caused by the working loss and any cost spent for corrective maintenance or spare part replacement. High level and catastrophic on node 2 caused by tank overflow and vapor emission while accumulation process. It makes the company has to spend some money to replace the loss of working loss in fuel accumulation process.
Node 3 has final risk on medium level in filling shed process where the impact appeared is hydrocarbon vapor emissions. It is in contrast with final risk with high level and catastrophic which occur while pumping fuel, fuel pipe distribution and filling shed. The impact appeared are such as leaks, hydrocarbon vapor emission, and overfill the tank car. This impact is rated high because of potential fire and it makes company to spend a lot of money to cover the loss of time and cost such as spare part or instrument replacement, product contamination and working loss. By those explanations, it can be seen that there is a relationship between risk impact, economic impact, and decision impact.

### 3.3. Risk Analysis

ANFIS-LOPA decision impact to show risk calculations inflicted on some a scenario based on data identification danger of company the management who performing calculations losses on fuel distribution in counting scenario against the risk of total economic impact per yearCalculation can be done using equation (5).

\[
\text{Total Impact/Year} = \text{Risk Probability Total} \times \text{Economic Impact/Loss Event}
\]

To take the risk of miscalculation that has an impact that is been made on the node 1 to node 3, can see the relationship between risks losses for the company as follows:

- The average decision impact node 2 to node 3 = 0.6988
- Losses during the process of fuel hoarding to the distribution of Rp 6,756,600,500
- The impact of the total losses per year = 0.6988 * Rp 6,756,600,500
- Companies experienced losses per year at the nodes 3-2 is Rp 4,721,512,429

Losses/year nodes 1-3 on the scenarios that have been made showing that the value of Rp 4,721,512,429,- is medium categories can be classified in accordance with the risk matrix company, standard CCPS 2008, and AS/NZS 4360:2004. The results of the impact probability decision can be used to calculate the resulting impact/year tailored to existing scenarios. Calculations can be performed on each scenario or scenario total as has been done in the calculation of node 2-3 above. This can simplify the management of total risk estimation in doing with regard to the impact of losess company in accordance with the desired scenario.

### 4. Conclusion

HAZOPS study can be applied to the fuel distribution system in Instalasi Surabaya Group (ISG) PT. Pertamina Tanjung Perak for qualitative analysis shown in HAZOPS worksheet. Quantitative analysis showed by LOPA result for risk analysis as SIL rating node 1 to 3, they are NR 33,33% for node 1, 54,55% for node 2, and 16,67% for node 3; SIL 0 as 50% on node 1, 18,18% on node 2 and 33,33% on node 3; SIL 1 as 16,67% on node 1 and 27,27% on node 2. ANFIS Layer of Protection has been built in fuel distribution system with output such as severity risk impact, SIL rating, economic impact, and decision impact. Decision impact in node 1 to 3 scenarios give output that affect the safety and economic aspect of company and some factors such as human, environment, asset, and reputation. ANFIS Layer of Protection produce the output of SIL 1 to 4 scenarios at node 1, 1 scenario with SIL 3 and NR, as well as 3 scenarios of SIL 1 on node 2, and the node 3 by 5 scenarios with SIL 1, SIL 2 3 scenarios and 2 scenarios with SIL 3 on node 3.

### 5. References
