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HAZOP Study Base Layer of Protection Analysis at Steam Turbin 105-JT Case Study : Amonia Plant-1, Petrokimia, East Java-Indonesia

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ABSTRACT

Being a essential element of life, the requirment for food product is in incricing in Indonesia. Food can demans can be met only if supported by strong fertilizers industry. To achieve this purpose the current study is being conducted to determine the possible risks and hazards in the failure of the 105-JT steam engine pad process at PT. Petrokimia Gresik. In addition, aims to increase the safety value of a plant in to prevention from risk and relation of possible process failure by increasing the SIL value of 105-JT steam turbine. From the HAZOP analysis, it is found that the failure with highest risk is the failure caused by malfunction of governor valve with good wear and tear on bearing component and nozzle. All the three are categorized as high risk with H value of 15. From the result of risk reduction process analysis at 105-JT by using LOPA the study recommends to add low low-low alarm (SALL) in process related with governor. As well as recommendations to add a temperature occurrence of vibration. After considering the data analysis and discussion. it is concluded that adding speed alarm LL on SI 1005 and BPCS 105-JT temperature control with temperature alarm HH on the steam turbine 105-JT is needed. There are also some other recommendation regarding to the safety of the gas scrubber, which is to recapitulate more accurate log sheet data, and make preventive maintenance scheduling to the reduce failure rate

INTRODUCTION

With given its role in maintaining state stability and its relation with poverty alleviation in Indonesia. Indonesia's food needs supported by strong fertilizer industry. The important factors that can enable fertilizer industries to be strong and sustainable are maintenance and improvement of reliability every equipment and instrument being deployed in the fertilizer industry.

PT. Petrokimia Gresik is one of the large-scale enterprises engaged in the production of fertilizers (Nitrogen and Phosphate fertilizers) and non-fertilizers (Ammonia). At factory 1 (Ammonia) at PT. Petrokimia Gresik one of the main components is 105-JT steam turbine engine. This machine serves as a propulsion compressor 105 JLP and a compressor 105 JHP. One of the steam turbines used by the fertilizer company PT. Petrokimia Gresik is 105-JT, at Plant 1 ammonia production process. The function of the 105-JT component is to drive the compressor 105 JLP and 105 JHP. The 105-JT turbine is driven by extraction vapor from HP Turbine (101-JT and 103-JT) in the form of medium pressure steam and supported by the production of steam regeneration from Waste Heat Boilers (Tawfeic, 2013) (Astrom, 1999).

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The process design is very important for to succeed or fail in 105JT steam turbine. If the system fails, then the whole process at the ammonia plant also gets ceased. This is also exacerbated by the absence of a backup steam turbine engine in anticipation of failure. This study aims to provide recommendations based on SIL calculation with Layer Of Protection Analysis (LOPA) method and risk assessment with Hazard and Operability Study (HAZOP) analysis to achieve work safety in process industry (Morrison *et al*, 2012). The Steam Turbine 105-JT at Ammonia Plant is the object to be analyzed related to risk and value of SIL Steam Turbine 105-LT is one of the steam turbines used at PT. Petrokimia Gresik, which functions as the driver 105 JLP and 105 JHP compressor. The steam turbine 105-JT is driven by the steam extraction from HP Turbine (101-JT and 103-JT), which is in the form of medium pressure steam, and also supported by production of steam regeneration from Waste Heat Boilers.

The importance of the study is that this manuscript can be used as guideline when a company is in consideration to run a better safety system, and as a recommendation to perform actions regarding the potential hazard, by doing a preventive action in order to prevent the potential hazard that may happen in the steam turbine. By doing so, it is expected tha the potential failure in the steam turbine can be reduced. By emphasizing the manuscript it can be said that this subject of research contributes in the process of a plant down the period in a systematic manner so that the risks such as material loss, environmental issues and human life threats can be mitigated

MATERIALS AND METHODS

2.1. Hazard and Operability Study (HAZOP):

Hazop is a hazard identification and analysis technique. There are some basic objectives of HAZOP study analysis (Nolan, 1994), including: To identify the inputs and causes of all changes in process function deviations, process output so that all major hazard levels and problems of operational system can be determined. The HAZOP analysis contains several important elements: Analysis process is a creative process that systematically use some guideword to identify deviations into the potential dangers of the design process and use this aberration as "triggering device" as a guide in the analysis of identification potential hazards, impact or the consequences that may occur. HAZOP analysis performed by personnel with basic knowledge about the process and analyzed using a logical mindset in every definition of the potential hazards. Any problems that finished identified, documented in an assessment table. HAZOP analysis there is some parameters that are standard in determining the value and level of danger in every component. Parameters used include; likelihood, consequence, and risk matrix. Likelihood is the chance of risk of harm to the components. Parameters used refers to the likelihood that the standard criteria likelihood "Production Departmen I PT. Petrokimia "shown Table 1.

Table 1: Criteria Likelihood PT. Petrokimia Gresik [1]

No	Ranking	Description
1	*Brand New Excellent*	Risk frequency of occurrence is less than four times in 10 years
2	*Very Good / Good Serviceable*	Risk of 4-6 times in 10 years
3	*Acceptable*	Risks occur between 6-8 times in 10 years
4	*Below Standard / Poor*	Risks occur between 8-20 times in 10 years
5	*Bad / Unacceptable*	Risk occurs 10 times in 10 years

Consequence parameters are describes the level of danger of the impact caused by the risk of deviations from the desired state or operating out of control. Reviews carried out based on the impact and the effect on factory activity and production. Standards to determine the consequence refers to the standard criteria factory consequence I PT. PKG shown by Table 2.

Table 2: Criteria Consequence PT. Petrokimia Gresik [1]

No	Ranking	Description
1	*Insignificant*	Sources of risk (elements / components / objects in the activity) are not impacted at all, consequently no significant effect on the continuity of activities, so that activities remain implemented
2	*Minor*	Sources of risk (elements / components / objects in the activity) have little impact, resulting in little impact on the continuity of activities, so that activities still happen
3	*Moderate*	Sources of risk (elements / components / objects in the activity) of a moderate impact, the result was the continuation of activities, so that activities still happen
4	*Major*	Sources of risk (elements / components / objects in the activity) have a major impact, consequently significantly to the continuity of the activity, but the activity can still be implemented, although not optimal
5	*Catastrophic*	Sources of risk (elements / components / objects in the activity) have an enormous impact, the consequences are very significant to the continuity of activities, so that activities cannot be implemented

Risk ranking is the result of multiplying the likelihood and consequence hazard criteria will be displayed in the matrix, where Risk = Consequence (C) x Likelihood (L), which is shown by Table.3.

Table 3: Risk Matrix ranking PT. Petrokimia Gresik [1]

Likelihood	Consequence				
	1, *Insignificant*	2, *Minor*	3, *Moderate*	4. *Major*	5, *Catastrophic*
1.*Brand New Excellent*	L1	L2	L3	L4	M5
2.*Good*	L2	L4	M6	M8	M10
3.*Acceptable*	L3	M6	M9	M12	H15
4.*Poor*	L4	M8	M12	H16	H20
5.*Unacceptable*	M5	H10	H15	H20	H25

Where: L =*low risk ;* M = *moderate risk ;* H =*high risk*

2.2. Safety Integrity Level (SIL):

Safety integrity level is a measure that states the magnitude of PFD of a system. While the PFD or probability failure on demand is a possible failure of a component or system when it is needed to work. The standard is shown Table 4.

Table 4: Safety Integrity Level for SIF [9]

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

Source: ISA TR 84.00.02-2002

Safety integrity level (SIL) is determined by calculating the probability of a failure will occur using the equation.

$$\lambda = 1/MTTF \tag{2.1}$$

Where: λ = *failure rate* (laju kegagalan); MTTF = Mean Time to Failure

Likelihood obtained from the comparison of the operating time of the components of the average number of component failures to the time following failure.

$$Likelihood = \frac{\text{Operatingtime}}{MTTF} \tag{2.2}$$

Metode in SIL calculations using quantitative methods derived from the calculation of the repair data as well as instrument implemented. The configuration of the equipment connected in series, the will be calculated failure rate. For configuration, Moon channel the formula used to calculate the PFD is [10]:

$$PFD_{1oo1} = \lambda^{DU} x \frac{TI}{2} \tag{2.3}$$

$$PFD_{1oo2} = \frac{\lfloor(\lambda^{DU})^2 x TI^2\rfloor}{3} \tag{2.4}$$

$$PFD_{1oo3} = \frac{\lfloor(\lambda^{DU})^3 x TI^3\rfloor}{4} \tag{2.5}$$

$$PFD_{2oo2} = \lambda^{DU}\, x\, TI \tag{2.6}$$

$$PFD_{2oo3} = (\lambda^{DU})^2\, x\, TI^2 \tag{2.7}$$

$$PFD_{2oo4} = (\lambda^{DU})^3\, x\, TI^3 \tag{2.8}$$

Where:

PFD_{MooN} = *Probability Failure on Demand Average*

λ^{DU} (Lambda) = *failure rat*

TI = *Interval time / test function (hour)*

$$PFD_{sys} = PFD_s + PFD_I + PFD_{fe} \tag{2.9}$$

Where:

PFD_{sys} : PFD rate from safety function-safety related system

PFD_s : PFD from sensor *subsystem*

PFD_l : PDD from DCS

PFD_{fe} : PFD from final *element subsystem*

2.3. Layer of Protection Analysis (LOPA):

LOPA is a semi-quantitative method that has a function to determine the value of SIL that is appropriate for system security conditions. Basic process control system (BPCS) is the most basic element in the course of the process, namely by designing how the best design of a system, so its capacity and reliability in accordance with the process or conditions where it will work. It says a process has a general design process if it has been designated maximum and minimum conditions of process parameters. BPCS is one protection layer that aims to monitor and control the course of a process. The course of the process is always evaluated through the set point that has been established company. BPCS is one of the most significant layers in relation to minimize system failure. BPCS said to be installed if there are elements sensor, logic solver and final element.

Fig. 1: Layer of protection analysis LOPA (Kenexis, 2014)

Alarm is the next level protection layer after BPCS. Alarms can be connected or separated with BPCS. The alarm will sound when the system indicates a deviation process beyond the company's tolerance limit; the alarm can be HH (high high) and LL (low low). While the Additional mitigation layer is one of the usual protection layer of Safety Instrumented System (SIS). If the process control system and operator fail to perform tasks in its efforts to secure the operation and safety of components and systems, the SIS will automatically actively work to protect the plant from the possibility of more severe damage.

2.4. Flowchar of Research:

esearch methodology is a series of activities carried out from the beginning to the end to achieve the objectives of this final project. Figure 2 is a flow of research methodology to be conducted in Figure 2.

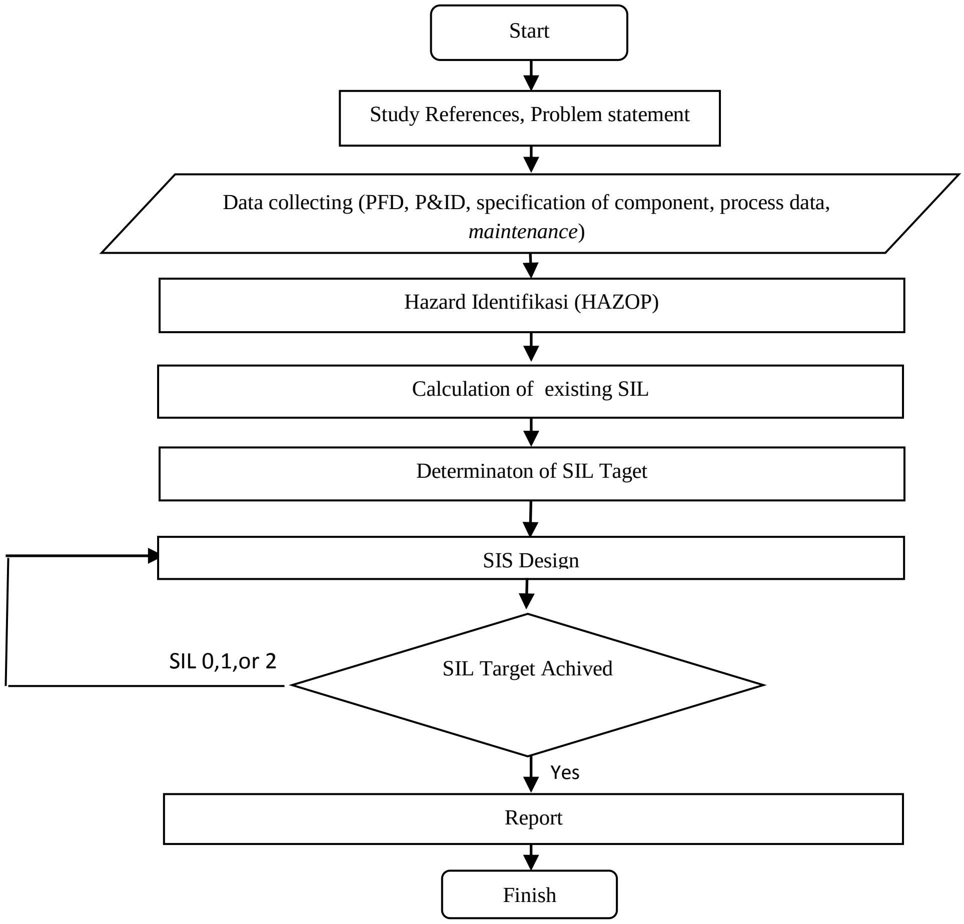

Fig. 2: Flowchart of the Research

Literature study is a follow-up of the formulation of the problem. Which is done by studying literature, journals related to themes and consultations with supervisors or engineers who are in the field? Data collection is done by taking the data in the form: Data specification of 105-JT steam turbine component; P & ID and PFD plant Ammonia Factory; Log sheet instrumentation process data components and mechanical components compilers node steam turbine 105-JT taken for the period October, November, and December 2015; Maintenance data in the form of repair, replacement, and calibration of components taken during the last ± 10 years of 105-JT steam turbine engines available at Maintenance Dept. 1. In addition, interviews with operators and SOP related implementers when required.

The 105-JT steam turbine hazard analysis with the HAZOP (Hazard Operability Study) method has the following stages: Determining control instruments and mechanical components acting on 105-JT steam turbine.; Determine the guideword and deviation process (deviation). In the case of this study used Xbar and s chart with the following parameter values: Control Limits Factor for averages (A3) = 0.606 and Factor for Limits of Standard Deviation, B3 = 0.565, B4 = 1.435; Analysis of the causes of the deviation, and its impact on the continuity of the process at the 105-JT node. In addition, determine the severity using scale consequences and likelihood.

RESULTS AND DISCUSSION

3.1. Risk Analysis:

A process is said to be deviating if the standard deviation value obtained on the Xbar Chart chart of the reading point has passed the upper limit (UCL) or lower limit (LCL). Where it is known that UCL and LCL deviations have passed three times the standard deviation (3σ). Shown in Figure 3.

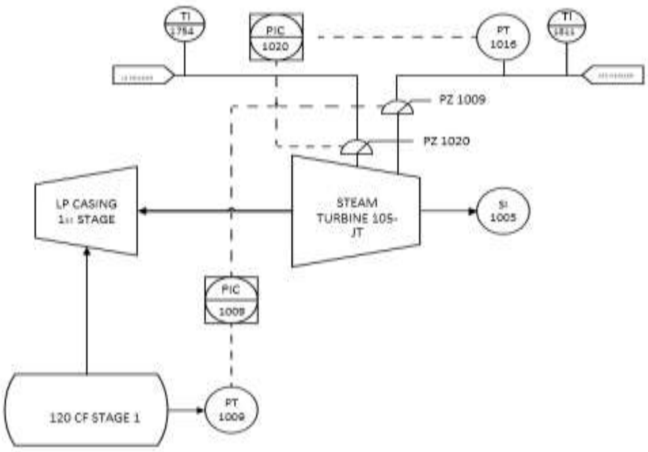

Fig. 3: P&ID 105-JT

The 105-JT steam turbine process is controlled by 2 pieces of control loop, i.e. PT 1009 on governor and PT 1016 for assembly valve assembly. There are also indicators used to monitor temperature at the 105-JT node, TI 811 on MSHeader line and TI 1754 on LS Header. Next, there is also SI 1005 that serves to control the speed of rotation 105-JT axis. For tag number PT.1009. Figure 4. Where CL = 0.0584, UCL = 0.0587 and LCL = 0.0581 Kg / cm2. With the percentage exceeding the upper deviation of 12.5% a land for the lower deviation of 16.7%.

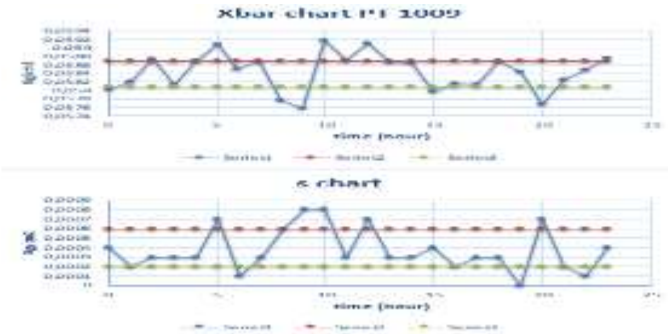

Fig. 4: GrafikProses PT 1009

For Tag Number: PT1016, Figure 5. From the process data obtained graph control chart where UCL = 3.4448 and LCL = 3.4324 Kg / cm2. With the average process value of 3.4386 Kg / cm2, it is found that the upper deviation = 33.3% and the bottom deviation = 29.17%...

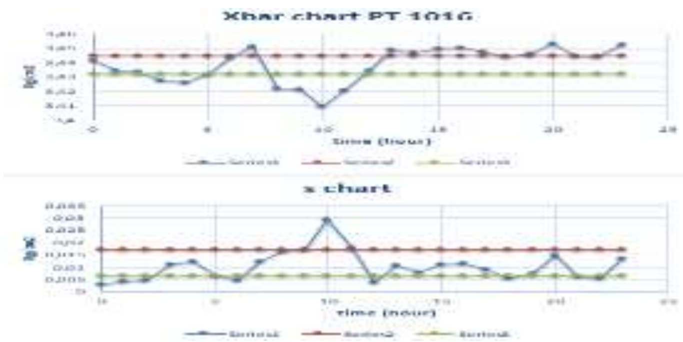

Fig. 5: Grafik Proses PT 1016

For Tag Number: SI 1005, Figure 6. Where UCL and LCL are 8226, 96 and 8199, 92 RPM, respectively, and the amount of CL = 8213, 44 RPM.

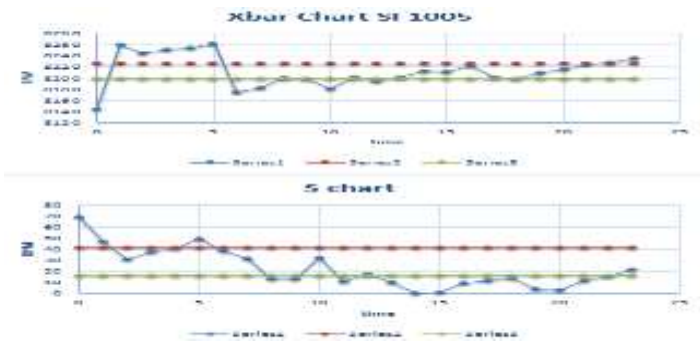

Fig. 6: Grafik Proses SI 1005

Maka didapat probabilitas proses menyimpang pada batas atas dan bawah = 25% dan 12,5%.

In Tag Number: TI 1754, Figure 7. After calculation found that the value of CL = 182,114oC, UCL = 182,6003oC and LCL = 181,6278oC. With an upper and lower deviation probability of 25%.

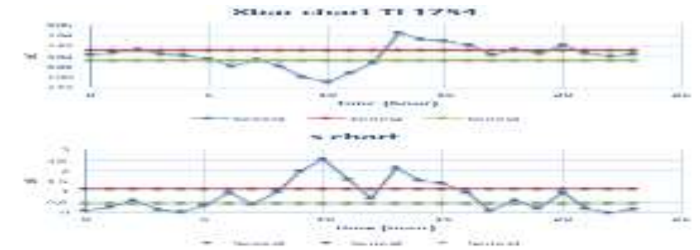

Fig. 7: Grafik Proses TI 1754

In Tag Number: TI 1811, Figure 8. Where UCL = 369,47oC and LCL = 369,01oC. With CL = 369.24, the process deviates at the upper and lower limits with possibilities of 8.33% and 20.83%.

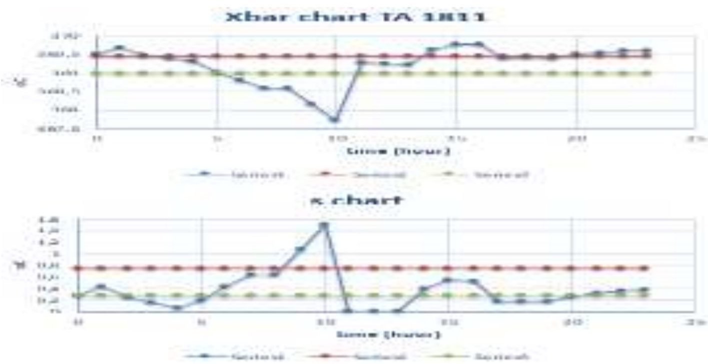

Fig. 8: Grafik Proses TI 1811

Table 5: Analysis of Deviation

Component	Description	Guide Word	Deviation
PT 1009	Pressure Transmitter	High	High Pressure
		Low	Low Pressure
PT 1016	Pressure Transmitter	High	High Pressure
		Low	Low Pressure
Trip Throttle Valve	Control Valve	Close	failed to close
PZ 1009 (Governor Valve)	Control Valve	Open	failed to open
		High	high speed
		Low	Low Speed
PZ 1020 (Admission Control Valve)	Control Valve	Close	failed to close
Gasket	mechanical component	High	High leakage of steam
nozzle	mechanical component	High	High frequency of Vibration
Labyrinth	mechanical component	High	High leakage of steam
Bearing	mechanical component	High	High frequency of Vibration and High Temperature

SI 1005	speed indicator	High	high speed
		Low	low speed
TI1754	temperature indicator	High	high temperature
		Low	low temperature
TA 1811	temperature indicator	High	high temperature
		Low	low temperature

3.2. Analysis of Potential, Causes and Effects of Hazards:

In HAZOP, the risk level is viewed from the likelihood value (incidence) and consequence caused.

Table 6: Likelihood

Instrument	MTTF	*Likelihood*	*L*	*C*	*RR*
PT 1009	28348,0	3,090165	1	5	M5
PZ 1009	12397,0	7,066226	3	5	H15
PT 1016	41224,0	2,124976	1	5	M5
PZ 1020	25104,0	3,489484	1	5	M5
TTV	6752,6	6,48643	2	3	M6
Gasket	7042,44	12,4389	4	2	M8
Nozzle	7210,01	12,1498	4	4	H16
Labyrinth	8528,3	10,2717	4	2	M8
Bearing	6236,61	14,0461	4	4	H16
SI 1005	20408	4,292434	2	4	M8
TI 1754	19446	4,504782	2	2	L4
TA 1811	175438,6	0,49932	1	2	L2

From HAZOP in Steam Turbine 105-JT persentage of *high risk* r = 25%.

Table 7: Hazard and Operability

component	Deviation	Cause	Consequences
PZ 1009 (Governor Valve)	failed to open	system control fail, no signal control, broken oil instrument	lack of steam in to 105-JT, compressor not working, steam turbine 105-JT trip
	high speed	a. system control fail, no signal control, broken air instrument b. High Flow steam	105-JT overspend, plant trip and shutdown cause equipment damage High Speed Turbine - High Vibration - Internal Damage
	Low Speed	a. system control fail, no signal control, broken air instrument b. Low Flow Steam	Low Speed, Low power Turbine, Low Power Compressor - Low Pressure on Discharge compressor
nozzle	High frequency of Vibration	the component is auks, turbine working in high pressure	high vibration occurred on 105-JT, and caused the other mechanical damage
Bearing	High frequency of Vibration and High Temperature	the component is auks, turbine working in high pressure	high vibration and high temperature occurred on 105-JT, and caused the other mechanical damage

Tabel 8: *Initiating Caused Likelihood*

Impact Event Description	Initiating Cause	MTF	ICL
105-JT over speed - High Vibration - Internal Damage – Trip Plant and Shutdown	More flow steam	12405	0,7
Lack of Steam in to 105-JT - Low Speed - Low Power Turbine - Low Power Compressor - Low Pressure on Discharge compressor	Less flow steam or failed to open	12405	0,7
High Vibration and High Temperature Occurred on 105-JT - Caused the other mechanical damage	Nozzle Aus	7210	1,2
	Bearing Aus	6237	1,4

3.3. LOPA Calculation:

A. Impact Event Description:

105-*JT over speed - High Vibration - Internal Damage – Trip Plant and shutdown;*

Initiating Cause **:** *More flow steam*

ICL = 0,7

- *Desain Proces* = 0,1
- BPCS = 0,1
- *Alarm* =0,1
- *Additional mitigation, Restricted access* = 0,5 *(human performance, under stress)*
- *Additional mitigation, Dike (Bunds)*, PRV = 0,01
- IEL = $ICLxPFD_1xPFD_2x\ldots\ldots xPFD_n$, IEL =$3,5x\ 10^{-6}$

PFD avg $=\frac{TMEL}{IEL}=$, with TMEL = $1\ x\ 10^{-5,}$ SIL *Determination* as *NO REQUIREMENT(NR) SIL.*

***B.Impact Event Description*:**

Lack of Steam in to 105-JT - Low Speed - Low power Turbine - Low Power Compressor - Low Pressure on Discharge compressor

Initiating Cause **:***Less flow steam or PZ 1009 failed to open*

ICL **=**0,7

- *Desain Proces* = 0,1
- BPCS = 0,1
- *Alarm* =1
- *Additional mitigation, Restricted access* = 0,5 *(human performance, under stress)*
- *Additional mitigation, Dike (Bunds)*, PRV = 0,01

IEL = ICLxPFD$_1$xPFD$_2$x… … xPFDn, IEL =3,5 x 10^{-5}

PFD avg =$\frac{TMEL}{IEL}$= , wirh TMEL = 1 x 10^{-5}, SIL *Determination as* **SIL 0**.

***C. Impact Event Description*:**

High Vibration and Temperature on 105-JT, and Other Mechanical Damage

Initiating Cause (1**)** **:** Nozzle aus

ICL **=** 1,2

- *Desain Proces* = 0,1
- BPCS = 1
- *Alarm* = 1
- *Additional mitigation, Restricted access* : 0,5 *(human performance, under stress)*
- *Additional mitigation, Dike (Bunds)*, PRV = 0,01

IEL = ICLxPFD$_1$xPFD$_2$x… … xPFDn, IEL =6 x 10^{-4}

PFD avg =$\frac{TMEL}{IEL}$= , with TMEL = 1 x 10^{-5}, SIL *Determination as* **SIL 1**.

***D. Impact Event Description*:**

HIGH VIBRATION HIGH TEMPERATURE ON 105-JT, OTHER MECHANICAL DAMAGE

Initiating Cause (2) **:** Bearing Aus

ICL **=** 1,4

- *Desain Proces* = 0,1
- BPCS = 1
- *Alarm* = 1
- *Additional mitigation, Restricted access* : 0,5 *(human performance, under stress)*
- *Additional mitigation, Dike (Bunds),* PRV = 0,01

IEL = ICLxPFD$_1$xPFD$_2$x… … xPFDn , IEL = 7 x 10^{-4}

PFD avg =$\frac{TMEL}{IEL}$= ,with TMEL = 1 x 10^{-5}, SIL *Determination* as S**IL 1**.

Conclusion:

Based on the data analysis and discussion above, it can be concluded that the results of the HAZOP analysis on Turbine 105-JT which were obtained at the age of three categories of risk ranking: Low = 16.7%; Medium = 58.3% 'Height = 25%. SIF Integrity Level st Steam Turbine 105-JT. PT. Petrokimia Gresik show values that vary from NR, SIL 0, to SIL 1 to High Risk Consequences Hazard. With various percentage such as 25% NR, 25% SIL 0, and 50% for SIL 1. To increase the SIL value or the need for loudspeakers on LOPA method, the recommended recommendation is to add Speed Alarm LL on SI 1005, and BPCS 105-JT temperature control with Temperature Alarm HH on Steam Turbine 105-JT.

Regarding the system safety in gas scrubber the study provides some recommendations The first recommendation is to perform the recapitulation of log sheet data continuously and done in all the instrumentation elements, so that the data collected is more accurate. If the data is more accurate, the deviation that may occur in the process may potentially can be reduced, and it can also be detected earlier if there is any of it. The second recommendation is to implement preventive maintenance scheduling in all the components continuously The preventive maintenance schedule can be executed by correlating correlating the historical data of the failure. This historical data of failure can be used to predict the potential upcoming failure, by seeing the failure interval time pattern . Through analysis of failure date estimation, the preventive maintenance can be set before the estimated time of failure occurs. So, it is expected that the components that have not failed, can lead to a deviation in the process. By doing this, it is expected that the condition of the components can be well-maintained. And, if there is any undesired condition, it can be detected earlier so that the failure rate of all the installed components can be reduced. If the failure rate of all the components can be reduced, the occurrence of failure to the deviation in the process can also be reduced.

As mentioned in the beginning, this manuscript can be taken as a guideline for future studies and if the company is in consideration to run a better safety system and as a recommendation to perform the action regarding the potential hazard, by doing a preventive action in order to prevent the potential hazard that may happen in the steam turbine. The action performed here has been implemented as per the recommendations provided in the previous section which are to recapitulate more accurate data and to make preventive maintenance scheduling. By doing so, it is expected that the potential failure in the steam turbine can be lowered. By emphasizing the manuscript, it can be said that this subject of research contributes in the process of a plant down the period in a systematic manner so that the risks such as material loss, environmental issues and human life threats can be mitigated.

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