Safety Integrated Level Analysis and Risk Management in Steam Drum Based on the Octave Software

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Abstract: As the Level of risk increase, better protection systems are needed to control them. One way to find out the system's performance is Safety Integrated Level. SIL is a degree of SIF able to implement necessary risk mitigation successfully. SIF comprises sensors, a Logic Solver, and final control elements. In this study, the safety levels of the steam drums use the SIL method, with nodes studies on temperature, pressure, and levels. The logic solver used a DCS solver, and Finale control elements used the main steam valve, valve separator, and water steam valve. Calculate SIL value using Excel and Octave software. Octave software is used to determine the level of safety on components automatically. The SIL calculations obtained a PFD value from a sensor at 0.0242656, PFD from the logic solver at 0.01171875, and PFD from the final control element was 0031280256. Based on the PFD value that has been obtained, PFD would be quantified and average PFD average by 0.067781661, thereby landing a risk reduction factor (RRF) of 14.75325. Drum steam can be categorized as having a safety integrated level (SIL) 1. the level of safety on the steam drum component is classified as safe. By consistently doing regular maintenance.

1 INTRODUCTION

A steam drum is one of the components of the water pipes that serve as reservoirs of water and water vapor and separate water vapor from water in forming superheater steam. In the steam of the drums, water is pumped by the boiler-circulation pump to the raisins tube/wall tube to get to the saturation vapor phase (Eliza Marceliana Zeinda,2017)

In Indonesia, job accidents occur in a plant environment caused by workers and plant components. According to the steam laws of 1930 and law no. 1 in 1970 on job safety that companies using the boilers were obliged to do an OHS program to reduce the number of accidents. A company needs protection and work in its business. So, it needs to apply risk management (Steam laws Kemnaker, 1930).

Every power plant has a standard for implementing risk management. It is critical because it concerns the reliability of an instrumentation system. As the danger is vital, better protection systems must control it. One method used to determine the performance is using the safety system (SIL) method (Vimalasari,2016).

SIL is a degree of SIF able to implement necessary risk mitigation successfully. The SIF of SIS is usually composed of sensors, programmable logic breakers, and late control elements (FCE). SIL herself refers to the possibility of SIF failure (PFD). The higher the SIL value, the PFD of SIS gets lower. The value of PFD of each determines the SIL level of an SIS - each SIF of the SIS itself, the sensors, logic solver, and finale of element control (Fitrani Kamila,2016)

The safety integrated Level (SIL) is separated into four levels based on IEC 61508, SIL 1, SIL 2, SIL 3, and SIL 4. The above criteria, which is both qualitative and quantitative, provides a foundation for determining SIL in general. The important test criteria of the products generated determine the formulation of a category SIL evaluation. Fire, materials quality, mechanical impact, electronic operation, and leak tests are just a few examples (Fitrani Kamila,2016).

This follows the need for a study to identify any potential dangers to the system and is expected to be able to recommend proper maintenance so that the components in the system can function properly, can identify a systematic operating process, and determine any deviation in the process that could lead to unwanted accidents or accidents.

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2 ANALYSIS METOD

2.1 Safety Integrated System

A Safety Instrument System is a collection of sensors, logic solvers, and final parts designed to protect the system in the event of a defiant operation without endangering people, the environment, or a valuable item

2.1.1 Sensor

The sensor is made up of several devices that monitor the process, such as transmitters and transducers. The sensor transforms physical data into electrical data that can be evaluated with an electric circuit

2.1.2 Logic Solver

The logic solver is a processor that takes an electric signal from one or more sensors and converts it into electric signals that are supplied to the final element

2.1.3 Finale Control Element

The final c*ontrol element* is part of the SIS, and its purpose is to *act* to return to a safe state. The valves and actuators are the last component.

2.2 Safety Instrument Function

SIF refers to a set of tools designed to lower the risk of a given danger. SIF is a non-profit organization. When defined conditions are breached, automatically bringing an industrial process to a safe state, allowing a method to move forward safely when stated conditions allow, and taking measures to reduce the consequences of an industrial hazard. It consists of elements that recognize an impending hazard, decide to act, and then put in the necessary effort to bring the process to a safe state.

2.3 Safety Integrated Level

SIL is a level of SIF that can successfully perform risk mitigation. Sensors, programmable logic solvers, and Finale Control elements are commonly found in the SIS SIF (FCE). The Safety Integrated Level test is used to determine whether a system is safe.

SIL ratings correlate to the frequency and severity of hazards. They determine the performance required to maintain and achieve safety and the probability of failure. The higher the SIL, the greater the risk of failure. And the greater the risk of failure, the stricter the safety requirements.

The SIL value is calculated using maintenance data for each piece of BPCS-related equipment. This data on maintenance aids in determining the MTTF (Mean Time to Failure).

While the failure rate is calculated using the equation:

$$Failure\ rate\ (\lambda) = \frac{1}{MTTF} \quad (1)$$

Then, after the failure rate is known, the PFD value is calculated using the equation:

$$PFD = 1/2 * \lambda * Ti \quad (2)$$

where:

PFD = Probability of Failure on Demand

λ = failure rate (hour)

Ti = test interval (hour)

Table 1: SIL and required safety system performance low demand mode system.

Safety Integrated Level (SIL)	*Probability Failure on Demand (PFD)*	*Safety Availability (1_PFD)*	*Risk Reduction Factor (RRF)*
4	0.0001 – 0.00001	99.99 – 99.999%	10000 – 100000
3	0.001 – 0.0001	99.9 – 99.99%	1000 – 10000
2	0.01 – 0.001	99 – 99.9%	100 – 1000
1	0.1 – 0.01	90 – 99%	10 – 100

Table 1 illustrates that the system's higher PFD value necessitates a high level of safety. To put it another way, the more serious the failure, the higher the level of safety required to verify that the plan is safe to use. It also demonstrates that the program requires extra safety procedures to protect it from failure.

Probability of failure on demand (PFD) is the probability that a system will fail dangerously and not be able to perform its safety function when required

Computing the PFD for each SIF made up of the SIS and then calculating the overall PFD for the SIF can be used to calculate the SIL. The following equation is used to calculate the total PFD.

$$PFD_{Total} = PFD_{sensor} + PFD_{Logic\ Solver} + PFD_{FCE} \quad (3)$$

From the total it can be seen the value of risk reduction factor, RRF as follows:

$$RRF = \frac{1}{PFD_{Total}} \quad (4)$$

2.4 Octave

An octave is a GNU software used for numerical analysis and is equivalent to MATLAB software capabilities. This study uses octave software to automatically perform calculations and determine the steam drum's level of safety. Thus, choosing the SIL level on the steam drum component.

2.5 P&ID Steam Drum

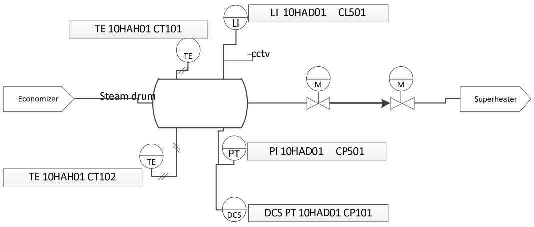

Figure 1: P&ID steam drum.

P&ID (pipe and instrumentation diagram) is a schematic of a process system's pipeline, equipment, instrumentation, and control system. The picture above shows several instrument temperatures, pressures, and levels, with TE CT101 as the input temperature sensor on the steam drum, which comes from the economizer output temperature. The sensor has CCTV, which functions to determine the value of the sensor needed by the local operator to see its value and the condition of the steam drum.

In addition, the steam drum also has a pressure transmitter sensor at the steam drum's output to determine the pressure value. And has a Level indicator to find out how much % the condition of the water level in the steam drum is. For the logic solver on the Steam Drum, DCS sends signals to the PLC and the CCR if there are other problems. After that, the steam drum has several final control elements in the form of valves such as the main steam valve, water valve, and separator valve.

2.6 Study Node

The study node's determination is based on the frequency of danger on the steam drum in the form of sensors, logic solver, and Finale control element. The resolution of the study node is obtained from the steam drum maintenance data.

Table 2: Study node steam drum.

SIS	Component	Component
Sensors	TE 10HAH01 CT101	TE 10HAH01 CT101
	LI 10HAD01 CL501	LI 10HAD01 CL501
	PI 10HAD01 CP501	PI 10HAD01 CP501
logic solver	DCS PT 10HAD01 CP101	DCS PT 10HAD01 CP101
finale control element	actuator	Main Steam Valve
		Valve separator
		Water Steam Valve

3 SIL CALCULATION

3.1 Sensor

According to the study node data received from the steam drum maintenance data, the steam drum includes three sensors: a temperature sensor, a pressure sensor, and a level sensor. The sensor has been repaired, and the Time to Failure has been calculated (TTF). The value of the Mean Time to Failure (MTTF) can be calculated using the TTF data, and then used to calculate the PFD value and failure data.

Table 3: Safety integrated level sensors.

SIS	components	MTTF	Failure Rate	PFD
sensor	TE 10HAH01 CT101	5772	0.000173	0.008316
	LI 10HAD01 CL501	5816	0.000172	0.008253
	PI 10HAD01 CP101	5844	0.000171	0.008214

Table 4: Safety integrated level sensors.

SIS	components	PFD average	RRF	SIL
sensor	TE 10HAH01 CT101	0.024783	40.3508	1
	LI 10HAD01 CL501			
	PI 10HAD01 CP101			

The MTTF value for each sensor is different, according to the equations above. The temperature sensor measures 5772, the pressure sensor measures 6816, and the level sensor measures 5844. The failure rate values of each temperature sensor, pressure sensor, and level sensor are 0.000173, 0.000172, and 0.000171, respectively, based on the computation (1) to estimate the failure rate value. After obtaining the failure rate, we can use the formulas (2) to compute the PFD and RRF for each sensor (4). The sensors system can be classified into SIL 1 with a PFD average value of 0.024783 and RRF 40.3508

3.2 Logic Solver

This steam drum uses a logic solver distributed control system (DCS). DCS is an integrated system using controllers, communication, protocols, and computer that can make it easier for users to control equipment using analog or digital signals from a control room.

The programmable logic controller (PLC) and other controllers are under DCS. So, this SIF is very crucial. If it is damaged, it can result in a data signal not being sent to the control room.

Table 5: Safety integrated level logic solver.

SIS	component	MTTF	Failure Rate	PFD
logic solver	DCS PT 10HAD01 CP101	4096	0.000244	0.011719

Table 6: Safety integrated level logic solver.

SIS	component	PFD average	RRF	SIL
logic solver	DCS PT 10HAD01 CP101	0.011719	85.33333	1

After performing calculations based on maintenance data, the MTTF value in the logic solver is 4096. Based on the above calculations, the following PFD and RRF values are obtained 0.011719 and 85.333. So, the logic solver can be categorized into SIL 1.

3.3 Final Control Element

The final element is part of the SIS, and its purpose is to *act to* return to a safe state. The valves and actuators are the final element. The main steam valve, water valve, and separator valve are the final control elements in the steam drum.

Based on the calculation of the MTTF value, the MTTF of each FC is different. The failure value in FCE is obtained from the maintenance data, such as preventive maintenance data and damage in FCE. After getting the MTTF value, can receive each FCE component's PFD value to find the PFD average value and the RRF value on the FCE. Based on these calculations, it was found that the average PFD value is 0.03128, and the RRF value is 31.96905 so, so the FCE can be categorized into SIL 1.

Table 7: Safety integrated level finale control element.

SIS	components	MTTF	Failure Rate	PFD
finale control element	Main Steam Valve	5160	0.000194	0.009302
	Valve separator	3569	0.00028	0.013449
	Water Steam Valve	5628	0.000178	0.008529

Table 8: Safety integrated level finale control elements.

SIS	components	PFD average	RRF	SIL
finale control element	Main Steam Valve	0.03128	31.96905	1
	Valve separator			
	Water Steam Valve			

3.4 Safety Integrated Level Steam Drum

The value of the Safety Integrated Level (SIL) can be computed based on the failure data that happens in the instrument on the Steam Drum component to identify the level of safety on the Steam Drum component and the PFD (Probability Failure Demand) value.

Table 9: Safety integrated level on the steam drum.

SIS	components	MTTF	Failure Rate	PFD
Sensor	TE 10HAH01 CT101	5772	0.000173	0.008316
	LI 10HAD01 CL501	5816	0.000172	0.008253
	PI 10HAD01 CP101	5844	0.000171	0.008214
logic solver	DCS PT 10HAD01	4096	0.000244	0.011719
finale control element	Main Steam Valve	5160	0.000194	0.009302
	Valve separator	3569	0.00028	0.013449
	Water Steam Valve	5628	0.000178	0.008529

Table 10: Safety integrated level on the steam drum.

SIS	component	PFD average	RRF	SIL
Sensor	TE 10HAH01 CT101	0.067782	14.75325	1
	LI 10HAD01 CL501			
	PI 10HAD01 CP101			
logic solver	DCS PT 10HAD01 CP101			
finale control element	Main Steam Valve			
	Valve separator			
	Water Steam Valve			

From the SIL calculation, it is found that the PFD value of the sensor is 0.024782656, the PFD of the logic solver is 0.01171875, and the PFD of the final control element is 0.031280256. Based on the PFD value that has been obtained, could add up the PFD, and the average PFD value is 0.067781661 so that the risk reduction factor (RRF) value is 14,75325. Steam Drum can be categorized as having a safety integrated level (SIL) I.

SIL 1 is the best level of security because if the SIL is high, the risk of failure is high. SIL level power plant is specific that SIL 1 has a lower risk of failure compared to other plants such as nuclear. This SIL calculation can contribute to the powerplant by knowing the safety level of these components. So that SIL 1 on the steam drum component needs to be maintained. The value of SIL on the steam drum component can be added by adding a system with safeguards and SIS so that if the system experiences damage that cannot be handled, the system can still be repaired.

3.5 Prevention

A step done to avoid failure is prevention. To avoid failure, there are four types of layers. The following is a list of preventative categories:

3.5.1 BPCS

Normal Process Control System is a basic process control system that includes normal processes.

During normal functioning, manual control is the first line of defense. The BPCS is intended to keep the process running safely. If it fits the conditions, a regular operation BPCS control loop can be credited as an IPL.

3.5.2 Alarm

The alarm is not included in the IPL in terms of practical functionality. Alarms, on the other hand, should notify the operator if a failure happens, therefore the alarm may be significant because the operator could not respond if the layer is not triggered.

3.5.3 Operator

The operator is someone who oversees and manages the process. In this instance, the operator could assume responsibility for restoring the plant to a safe operating condition in the event of a failure. When the BPCS system fails, the operator's function as the IPL is critical for operators to maintain control.

3.5.4 SIS

When the BPCS and the operator fail to take over and restore a safe condition, the SIS could be activated. The SIS system runs on its own, with no intervention from the operator. In situations where the tolerance is exceeded, the system could actively safeguard you

3.6 SIL Calculator Octave

This study uses octave software to perform calculations automatically and determine the steam drum's level of safety.

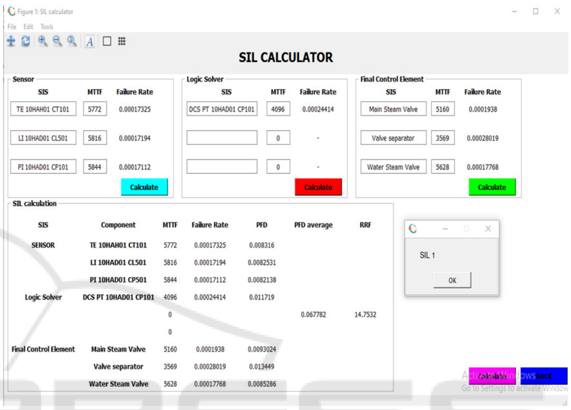

Figure 2: Sil Calculator.

To determine the value at the safety level for the component, first, fill in the MTTF value for each SIS and then calculate. Then the value from the calculation will be called back to the SIL calculation. If all the values are fulfilled, then by pressing the calculate push button below, it will automatically determine the safety level on the component via the message box.

4 CONCLUSIONS

Based on the data obtained and analyzed. The following are the findings of this research as SIL 1 includes steam drum components with SIF sensors, DCS, and Finale control features. The approach of substituting the failure rate of a small component in SIL calculations, notably by changing the TI value (time interval) and can also design a re-architecture of the Steam drum system, is one way to raise the level of safety. and the use of the SIL calculator makes it easier to analyze the value of safety on components

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