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Analisis HIRADC Sebagai Pencegahan Kecelakaan Kerja pada Pekerjaan Pemeliharaan *Major Overhaul* 50K STG PLTGU Tanjung Uncang PT. PLN Batam

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Abstract: *The electricity sector is categorized as a high-risk industry (asset-sensitive enterprise). At PT PLN Batam, particularly at the 124.5 MW Tanjung Uncang Combined Cycle Power Plant (PLTGU), the reliability of the Steam Turbine Generator (STG) system depends on routine large-scale maintenance, including the 50K Major Overhaul, which involves significant hazards such as high-voltage electricity, high pressure, extreme temperatures, and mechanical risks. This study aimed to analyze potential hazards, assess occupational risk levels, and determine appropriate control measures for the 50K Major Overhaul of the Steam Turbine Generator using the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method. A qualitative descriptive approach was employed through field observations, interviews, and document analysis. The results identified 11 maintenance activities, consisting of 6 High Risk and 5 Medium Risk activities before control implementation. The highest risk was associated with working at heights, high-pressure and high-temperature systems, high-voltage electrical work, and the use of power tools, with a maximum Severity value of 5. After implementing engineering controls, administrative controls, competency requirements for certified personnel, and the use of personal protective equipment (PPE), all 11 activities were successfully reduced to the Low Risk category, with the Likelihood value decreasing to 1. These findings demonstrate that the systematic implementation of the HIRADC method effectively reduces occupational risks and provides a practical framework for improving safety performance during major overhaul activities at combined-cycle power plants.*

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INTRODUCTION

Power plants are complex systems consisting of various equipment and machinery used to generate electrical energy through the conversion of energy from diverse primary sources. Most power generation facilities produce three-phase alternating current (AC) electricity and generally utilize synchronous generators driven by prime movers that obtain energy from fuel sources or natural resources (Roebidin et al., 2025). Based on the type of prime mover, power plants are classified into several categories, including hydroelectric power plants (HPP), diesel power plants (DPP), steam power plants (SPP), gas power plants (GPP), combined cycle gas and steam power plants (CCPP), geothermal power plants (GeoPP), and nuclear power plants (NPP) (Anshari et al., 2025). As one of the most important infrastructures supporting national development, power generation systems require high reliability to ensure continuous electricity supply for both public and industrial sectors.

PT PLN (Persero) is a state-owned enterprise fully owned by the Government of the Republic of Indonesia and serves as the largest electricity provider in the country. The company manages various

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aspects of the electricity sector, including generation, transmission, and distribution. As an electricity provider with highly asset-sensitive characteristics, PT PLN (Persero) and its subsidiaries depend heavily on effective strategic asset management to maintain operational reliability and business sustainability (Howay & Sukwadi, 2026). Strategic assets such as power plants, transmission networks, substations, and transformers have significant economic value and play an essential role in ensuring the continuity of electricity services (Febyola et al., 2025). Therefore, the management of asset performance, operational budget, and potential risks must be conducted effectively throughout the asset life cycle.

One of PT PLN (Persero)'s subsidiaries is PT Pelayanan Listrik Nasional Batam (PLN Batam), which is responsible for providing electricity services in Batam. PLN Batam operates several power generation facilities (PLN Batam, 2023), including the Tanjung Uncang Combined Cycle Power Plant (CCPP) with an installed capacity of 124.5 MW. This power plant applies combined cycle technology that integrates gas turbine and steam turbine cycles through a Heat Recovery Steam Generator (HRSG). This configuration improves thermal efficiency and contributes to reducing environmental impacts associated with power generation processes (Rusdinah & Tobing, 2025).

The operational reliability of a power plant is highly dependent on effective maintenance activities. Maintenance activities are essential to prevent equipment failure, ensure electricity supply reliability, and optimize operational costs. At the Tanjung Uncang CCPP, maintenance activities are conducted periodically based on manufacturer recommendations and equipment operating hours. One of the critical maintenance activities is the 50,000-hour Major Overhaul of the Steam Turbine Generator (STG), which involves complex processes, specialized equipment, and experienced technical personnel. Due to the complexity of these activities, systematic hazard identification and risk assessment are required to minimize the potential occurrence of occupational accidents.

Occupational safety risks remain a major concern in the electricity sector due to the characteristics of the work environment involving high-energy systems, heavy equipment, and complex maintenance activities. Data from the Ministry of Manpower of the Republic of Indonesia in 2023 recorded 173 occupational accidents in the electricity sector, with 27 cases resulting in fatalities. These accidents may occur due to direct contact with energized electrical systems, falls from heights, exposure to electromagnetic fields, and fire hazards (Mayansara et al., 2025). Occupational accidents are unexpected events that may result in losses affecting workers, operational activities, the environment, and company assets. Such incidents may arise from unsafe acts caused by human behavior or unsafe conditions related to workplace conditions and environmental factors (Thyroidi Prasojo & Jufriyanto, 2025; Fatkhul & Dwi Saputri, 2026).

According to Suhartina et al. (2023), occupational hazards can be categorized into ten types, including biological, chemical, electrical, gravitational, motion-related, mechanical, pressure-related, radiation, noise, and temperature hazards. To control these hazards, organizations require systematic approaches for identifying hazards, assessing risks, and determining appropriate preventive measures. Risk assessment is a structured process used to evaluate the level of risk and determine whether additional control actions are required (Syalomita et al., 2023). One of the approaches commonly implemented to support occupational safety management is the Occupational Safety and Health Management System (OSHMS), which aims to improve workplace safety protection through planned, measurable, and integrated procedures involving all organizational stakeholders (Theodorou & Tzovenis, 2024; Aji & Santoso, 2024).

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One method commonly applied within OSHMS implementation is Hazard Identification, Risk Assessment, and Determining Control (HIRADC). HIRADC focuses on identifying hazards, evaluating risks based on their likelihood and consequences, and establishing appropriate control measures. In addition, Job Safety Analysis (JSA) provides a systematic approach for analyzing work activities to identify potential hazards that may not be immediately recognized. The integration of HIRADC and JSA can provide a more comprehensive risk assessment framework to support effective occupational safety programs (Raharjo & Rachmawati, 2026).

Previous studies have demonstrated that the HIRADC method is effective in identifying workplace hazards, assessing occupational risks, and determining appropriate control strategies. Several studies have also integrated HIRADC with JSA to improve hazard identification within work processes (Ajslev et al., 2022). These studies indicate that HIRADC supports occupational safety programs by prioritizing risks based on their likelihood and severity, allowing organizations to establish more effective preventive measures (Mulyadin et al., 2025).

However, previous research has predominantly focused on general industrial environments, manufacturing processes, construction projects, and electrical distribution activities (Davies et al., 2025). Limited studies have investigated the implementation of HIRADC in complex maintenance activities within combined-cycle power plants, particularly during large-scale Steam Turbine Generator (STG) Major Overhaul activities. Furthermore, previous studies generally emphasize hazard identification and risk classification without comprehensively evaluating changes in risk levels before and after the implementation of control measures under actual maintenance conditions.

Therefore, this study addresses these limitations by applying the HIRADC method specifically to the 50,000-hour Major Overhaul of the Steam Turbine Generator (STG) at the Tanjung Uncang Combined Cycle Power Plant. This research provides an activity-based hazard assessment, evaluates occupational risk levels before and after control implementation, and formulates practical control recommendations based on occupational safety principles. The findings are expected to contribute theoretically by expanding the application of HIRADC within high-complexity power plant maintenance environments and practically by providing a structured risk management approach to support safer maintenance planning in the power generation industry.

This study aims to analyze occupational hazards during the 50,000-hour Major Overhaul of the Steam Turbine Generator (STG) at the Tanjung Uncang Combined Cycle Power Plant using the HIRADC method. Specifically, this research aims to identify potential hazards, assess associated risk levels, evaluate the effectiveness of implemented control measures, and formulate recommendations to strengthen occupational safety and health practices in high-risk power plant maintenance activities.

RESEARCH METHOD

Research Design and Data Collection

This study employed a descriptive research approach supported by qualitative hazard identification and semi-quantitative risk assessment using the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method. The research was conducted to identify potential hazards, evaluate occupational risks, and determine appropriate control measures during the 50,000-hour

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Major Overhaul of the Steam Turbine Generator (STG) at the Tanjung Uncang Combined Cycle Power Plant (CCPP), PT PLN Batam, Indonesia.

The research subjects were selected using a purposive sampling technique, involving personnel who had direct involvement and sufficient knowledge regarding STG maintenance activities. The selected informants consisted of Health, Safety, and Environment (HSE) personnel, maintenance supervisors, engineers, and technicians involved in the Major Overhaul process. These participants were selected because they possessed practical experience related to maintenance procedures, workplace hazards, and occupational safety practices.

Data collection involved primary and secondary data sources. Primary data were obtained through direct field observations, semi-structured interviews, and documentation of maintenance activities during the overhaul process. Field observations were conducted to identify work activities, potential hazards, and existing safety practices applied during maintenance operations. Interviews were conducted to obtain information regarding safety procedures, hazard perception, and the implementation of risk control measures. Secondary data were obtained from company documents, including Standard Operating Procedures (SOPs), previous HIRADC documents, maintenance records, occupational accident reports, technical manuals, and relevant scientific literature. Data credibility was strengthened through source triangulation by comparing observation results, interview findings, and available company documentation.

HIRADC Implementation Procedure

The research procedure was conducted through five systematic stages: (1) preliminary observation and document review, (2) hazard identification, (3) risk assessment, (4) determining control measures, and (5) evaluation of control effectiveness. The overall implementation process of the HIRADC method is illustrated in Figure 1.

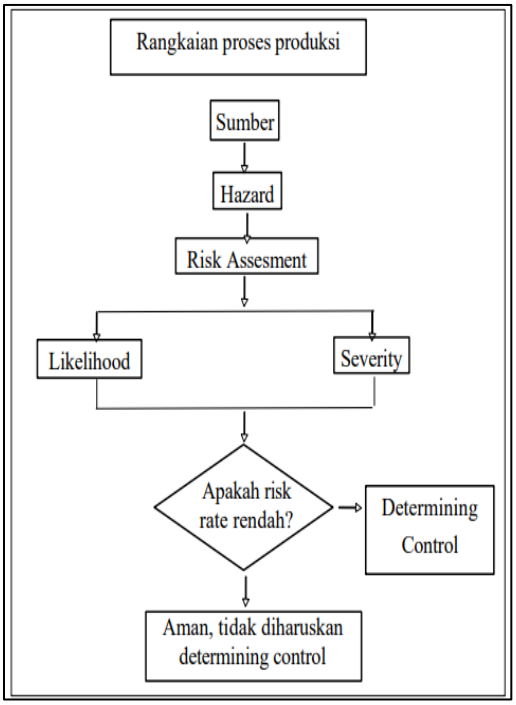

Figure 1. Flowchart of HIRADC Method Implementation

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The first stage involved preliminary observations and document reviews to understand the characteristics of the 50,000-hour Major Overhaul activities and determine the maintenance processes requiring further analysis. The second stage consisted of hazard identification by analyzing each work activity to determine potential hazards associated with human factors, work methods, materials, machinery, and environmental conditions.
The third stage involved risk assessment based on two main parameters: Severity and Likelihood. Severity represents the magnitude of consequences that may occur due to an incident, while Likelihood represents the probability of hazard occurrence during work activities. The risk value was calculated using the following equation:

Risk=Likelihood×Severity

The resulting risk values were categorized into five levels: Very Low, Low, Medium, High, and Extreme. The classification of risk levels was determined using the Risk Assessment Matrix based on the AS/NZS 4360:1999 Risk Management Standard. This standard was selected because it provides a systematic framework for evaluating and prioritizing occupational risks based on the relationship between likelihood and consequences.
The risk assessment matrix used in this study is presented in Figure 2.

Likelihood	Severity				
	A (Sangat Ringan)	B (Ringan)	C (Sedang)	D (Berat)	E (Sangat Berat)
5 (Sangat sering terjadi)	Moderate	High	High	Extreme	Extreme
4 (Sering terjadi)	Moderate	Moderate	High	High	Extreme
3 (Sedang terjadi)	Low	Moderate	Moderate	High	Extreme
2 (Jarang terjadi)	Low	Moderate	Moderate	High	High
1 (Sangat jarang terjadi)	Low	Low	Moderate	Moderate	High

Figure 2. Risk Assessment Matrix

Risk Control and Data Analysis

After risk levels were determined, the fourth stage involved establishing appropriate control measures using the Hierarchy of Controls approach. The selection of controls was conducted according to the effectiveness hierarchy, beginning with elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). This approach was applied to reduce identified risks and minimize the possibility of occupational accidents during STG maintenance activities.
The hierarchy of risk control applied in this study is presented in Figure 3.

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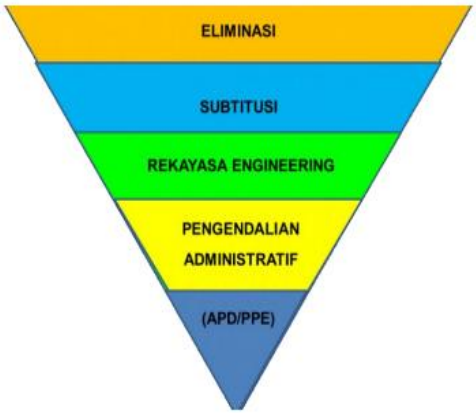

Figure 3. Hierarchy of Risk Control

The final stage involved evaluating the effectiveness of the implemented control measures by comparing the initial risk level before control implementation and the residual risk level after control implementation. The collected data were analyzed descriptively by evaluating identified hazards, interpreting risk categories, assessing risk reduction after control measures, and formulating recommendations to improve occupational safety and health performance during the 50,000-hour Major Overhaul activity.

Through this methodological approach, the study provides a systematic assessment of occupational hazards and risk control strategies in a high-complexity power plant maintenance environment.

RESULTS AND DISCUSSION

Characteristics of STG System and Maintenance Activities

The research was conducted during the 50,000-hour Major Overhaul activity of the Steam Turbine Generator (STG) at the Tanjung Uncang Combined Cycle Power Plant (CCPP), PT PLN Batam. The STG system represents a critical part of the combined-cycle power generation process because it converts thermal energy from steam into mechanical energy and subsequently into electrical energy through the generator system.

A Combined Cycle Power Plant (CCPP) integrates a Gas Power Plant (GPP) and a Steam Power Plant (SPP). The exhaust gas generated from the gas turbine, which generally has a temperature above 400°C, is utilized through a Heat Recovery Steam Generator (HRSG) to produce steam that drives the steam turbine. This process improves overall thermal efficiency by utilizing waste heat from the gas turbine cycle (Khahro et al., 2021). The combined-cycle process applied at Tanjung Uncang CCPP is presented in Figure 4.

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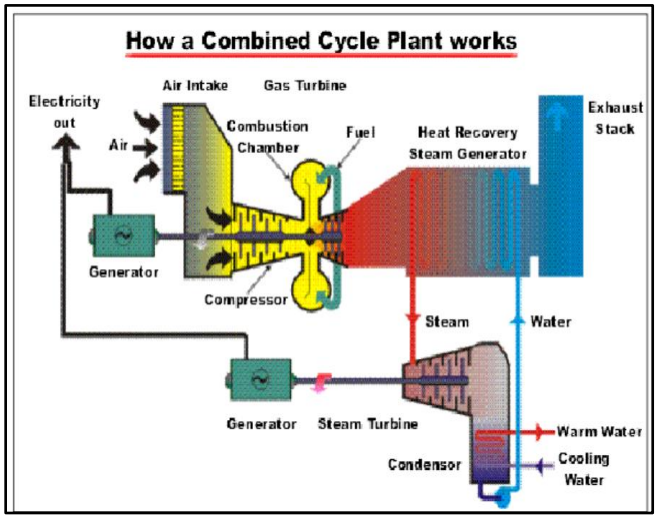

Figure 4. Combined Cycle Power Plant Cycle

The STG system analyzed in this study consists of several main components, including the steam turbine, generator, condenser, cooling tower, feed water tank, and feed water pump. These components operate as an integrated system, where failure or malfunction in one component may affect the reliability of the entire power generation process.

Figure 5. STG Components of Tanjung Uncang Combined Cycle Power Plant

The steam turbine functions to convert high-temperature and high-pressure steam energy into mechanical rotation energy. Steam supplied from the HRSG enters the turbine blades and produces shaft rotation that drives the generator. Due to its operating conditions involving high temperature, pressure, and rotating equipment, maintenance activities on steam turbines require strict safety controls (Rezky, 2020).

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Figure 6. Steam Turbine of Tanjung Uncang Combined Cycle Power Plant

The generator converts mechanical energy from the turbine into electrical energy. Maintenance activities in this area require particular attention because electrical energy, stored energy, and potential equipment failure may create significant occupational hazards if isolation procedures are not properly implemented.

The condenser functions to condense exhaust steam from the turbine through heat transfer with seawater flowing inside condenser tubes. This process allows condensed water to be reused as boiler feedwater and improves turbine efficiency by maintaining vacuum conditions. However, inspection activities in the condenser and hotwell areas may involve hazards related to confined spaces, slippery surfaces, chemical exposure, and restricted access.

Figure 7. Condenser of Tanjung Uncang Combined Cycle Power Plant

The cooling tower supports condenser operation through heat transfer and evaporative cooling mechanisms. Hot water from the process system is distributed through the cooling tower and exposed to airflow to reduce temperature before being circulated back into the system.

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Figure 8. Cooling Tower of Tanjung Uncang Combined Cycle Power Plant

Supporting equipment, including the feed water tank and feed water pump, also plays an important role in maintaining steam cycle operation. The feed water tank functions as a storage reservoir for purified water, while the feed water pump transfers feed water within the system to maintain operational stability.

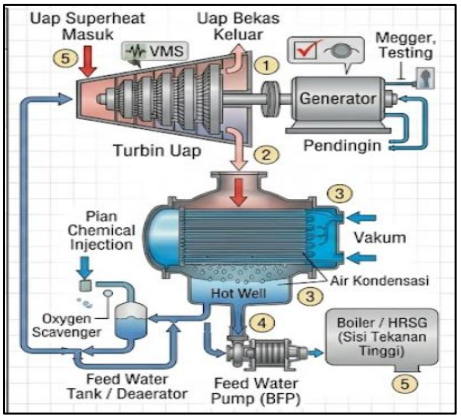

Figure 9. Steam Turbine Generator (STG) Components

The characteristics of these components indicate that STG Major Overhaul activities involve various potential hazards, including electrical energy, high temperature, high pressure, mechanical movement, lifting operations, and working at height. Therefore, systematic hazard identification and risk assessment are required to ensure that maintenance activities can be performed safely.

Hazard Identification Results During STG Major Overhaul

The hazard identification process was performed on various maintenance activities conducted during the STG Major Overhaul. The analyzed activities included condenser and hotwell inspection, steam turbine inspection, generator inspection, transformer inspection, cooling tower commissioning, lubrication system inspection, gland steam system inspection, and commissioning activities.

The identified hazards were classified based on five main factors: human, method, material, machine, and environmental factors (Devira Rona Prisnayanti & Evi Widowati, 2024). The assessment identified several potential hazards, including:

- working at height,
- exposure to high temperature and pressure,
- electrical hazards,
- lifting operations,
- power tool usage,
- chemical exposure,

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- fire and explosion risks,
- noise exposure,
- slip, trip, and fall hazards.

These hazards demonstrate that STG Major Overhaul activities involve complex interactions between workers, equipment, and operational environments. Therefore, hazard identification becomes an essential step to determine appropriate preventive and corrective measures.

HIRADC Risk Assessment Results

The identified hazards were evaluated using the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method. Risk assessment was conducted by considering Severity and Likelihood parameters. The calculated risk values were classified into several categories based on the risk matrix.

Table 1. HIRADC for the 50K Major Overhaul Maintenance of the Steam Turbine Generator (STG) at the Tanjung Uncang Combined Cycle Power Plant

Activity	Danger	Risk	*Risk Analysis*			Control	*Determining Control*		
			S	L	R		S	L	R
• *Inspection Condenser and Hotwell,* • *Inspection Turbine Steam, Gland Steam Condensor System* • *Inspection Transformator,*	Gravity	Working at heights	5	4	H	• Install barricades outside the work area and safety signs when installing scaffolding.. • Scaffolding may be used if it has been inspected by a competent and certified inspector from the Ministry of Manpower. • Attach inspection tags to the scaffolding. • Carrying materials or tools manually is prohibited, exceeding 5 kg. Any weight above 5 kg must be carried using a pulley.	5	1	L
• *Inspection* • *Condenser and Hotwell,* • *Cooling Tower Commisioning,* • *Turbine activity,* • *Gearbox activity, and all in commisioning*	Ergonomics	Working with hand tools or measuring tools	3	3	M	• Use hand tools/measuring equipment appropriate for the job. • Visually inspect before use. • Safety instructions in the instruction manual must be observed and followed. • Use hand tools correctly and safely. • Wear appropriate PPE.	3	1	L
• *Inspection Condenser and Hotwell,* • *Inspection Vacuum Ejector, System, Gland Steam*	Waste and chemicals	There is a rise rubbish waste and chemicals	3	3	M	• Restrict/barricade the work area if necessary. • Substitute with substances that are less hazardous to health, if possible. • Observe and follow the instructions in the Material	3	1	L

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Condensor System • *Inspection NDE,* • *Inspection Transformator*						Safety Data Sheet (MSDS) for the substances/materials used. • Keep away from heat sources. • Use an exhaust fan/blower for ventilation.			
• *Inspection Condenser and Hotwell* • *Inspection Colling Tower* • *Inspection Motor and Pump CWP* • *Start Turning Gear, Interloc Tes, Start Up Steam turbine*	Hot	Working Under High Pressure and Heat	5	4	H	• Ensure a hot work permit has been obtained. • Install barricades and safety signs in the work area. Other workers/unauthorized personnel are prohibited from entering the barricaded work area. • Maintain adequate ventilation in the work area and, if necessary, use an exhaust fan in the work area.	5	1	L
• *Inspection Condenser and Hotwell,* • *Inspection Vacuum Ejector, System, Gland Steam Condensor System* • *Inspection Generator,* • *Inspection NDE,* • *Inspection Transformator*	Gravity	Danger of slipping, tripping and falling on the same level	3	3	M	• Place cables outside of hazardous areas. • Remove unnecessary materials and tools from the work area. • Routes must be free of obstructions. Keep the work area clean and tidy. • Work access areas must be free of oil or other fluids. • Prepare a squeegee and secondary oil containment to clean up spilled oil. • Wear appropriate PPE.	3	1	L
• *Inspection Condenser and Hotwell,* • *Inspection Generator,* • *Inspection NDE,* • *Inspection Protection,* • *Inspection Lube Oil System , Gland Steam, Condsate, Calibration & cleaning control equipmen*		Working with power tools (pneumatic , electric, and hydraulic)	4	4	H	• Follow safety instructions and work procedures. • Use only power tools that have been inspected and declared safe for use. • Visually inspect power tools and their inspection tags before use • Use only power tools appropriate for the job. • Only trained and qualified workers should use power tools.	4	1	L
• *Inspection Condenser and Hotwell,* • *Inspection Vacuum Ejector,*	Gravity	Dangers due to impacts and scratches	2	4	M	• Only use tools appropriate to the job • The tools used must be suitable for use and functional. • Use trained workers	2	1	L

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System, Gland Steam Condensor System • *Inspection Generator,*		(head injuries, bruises, cuts, broken bones)				• Avoid sharp and pointed objects • Wear long sleeves • Use appropriate PPE.			
• *Inspection Condenser and Hotwell,* • *Inspection Vacuum Ejector, System, Gland Steam Condensor System* • *Inspection Generator,* • *Inspection NDE,* • *Inspection Transformator,* • *Inspection Protection, Turbine activity,*	Pressure	Danger due to fire or explosion	5	5	H	• Follow safety instructions. • Provide an exhaust fan to circulate air from the work area. • Check the air/atmosphere in the work area. • Clear the work area of flammable/explosive materials. • Barricade the work area to prevent access for other/unnecessary workers. • Provide a fire extinguisher as needed. • Maintain a minimum distance of 3 meters between fuel gas and oxidizing gases or	5	1	L
• *Inspection Condenser and Hotwell,* • *Inspection Vacuum Ejector, System, Gland Steam Condensor System* • *Inspection NDE,* • *Inspection Transformator,* • *Inspection Lube Oil System , Gland Steam, Condsate, Calibration & cleaning control equipmen* • *Inspection Colling Tower* • *Turbine activity,*	Ergonomics	Work with overhead cranes /load handling devices and handling suspended loads	5	5	H	• Prepare a lifting plan for critical and complex lifts. • Follow proper lifting procedures. • Maintain distance from the load. • Install barricades, if necessary, to prevent unauthorized personnel from moving away from hazardous areas. • Ensure the overhead crane unit has been inspected and certified by the Department of Manpower. • Conduct a manual inspection before use and inform your supervisor if any lifting equipment is damaged by marking it and then segregating it for use. • Overhead crane operators and riggers must be competent and certified by the Ministry of Manpower.	5	1	L
• *Inspection Generator* • *Inspection Lube Oil System , Gland Steam,*	Noise	Danger due to noise and lighting	4	3	M	• Try to choose a work area with low noise. • Follow all noise and hearing protection instructions. • Try to work in a brighter area.	4	1	L

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Condsate, Calibration & cleaning control equipmen • *Turbine activity,*							• Increase lighting if necessary and adjust it to the conditions. • Wear appropriate PPE.			
• *Turbine activity* • *Gearbox activity, and all in commissioning* • *Inspection Protection*	Electricity	Dangers due to electric current and high voltage	5	5	H	• Follow the 5 safety rules: 1. Isolate (LOTO) 2. Lock out to prevent restarting 3. Confirm that the equipment is de energized 4. Ground and short circuit 5. Cover or barricade nearby objects that are energized	5	1	L

Based on Table 1, eleven potential hazards were identified during the STG Major Overhaul activities. Before control implementation, six activities were classified as High Risk, while five activities were classified as Medium Risk.

The High Risk categories were mainly associated with:

- working at height,
- hot work involving high temperature and pressure,
- fire and explosion hazards,
- overhead crane operations,
- electrical systems.

These activities received high risk ratings because failures during execution may result in severe consequences, including serious injury, equipment damage, and disruption of power plant operations.

The Medium Risk categories were mainly related to ergonomic hazards, hand tool usage, material handling, noise exposure, and workplace conditions. Although these risks had lower consequences compared with High Risk activities, they still required appropriate controls to prevent accident escalation.

Evaluation of Risk Control Effectiveness

After hazard identification and risk assessment, control measures were determined based on the Hierarchy of Controls approach, including elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE).

Table 2. Distribution of Risk Levels Before and After Control Implementation

Risk Level	Before Control	After Control
High	6	0
Medium	5	0
Low	0	11
Very Low	0	0
Extreme	0	0

Table 2 shows that before implementing control measures, six activities were categorized as High Risk and five activities were categorized as Medium Risk. After applying control measures, all identified hazards were reduced to the Low Risk category.

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The reduction in risk level indicates that the implemented controls effectively reduced the probability of accident occurrence. Engineering controls, such as scaffolding inspection, installation of barricades, ventilation systems, and proper lifting equipment, reduced workers' exposure to hazardous conditions.

Administrative controls also contributed significantly through the implementation of work permits, safety procedures, competency certification, routine inspections, and supervision. In addition, Lockout/Tagout (LOTO) procedures were applied to electrical-related activities to prevent accidental energization during maintenance.

Although all identified risks were reduced to Low Risk, residual risks remain because several maintenance activities inherently involve hazardous conditions, including electrical systems, high-pressure equipment, lifting activities, and high-temperature components. Therefore, continuous monitoring, periodic HIRADC review, safety audits, and worker competency improvement remain necessary.

Discussion and Research Contribution

The findings demonstrate that HIRADC provides an effective framework for managing occupational risks during complex power plant maintenance activities. The reduction of all identified risks from High and Medium categories into Low Risk confirms that systematic hazard identification combined with appropriate control selection can improve occupational safety performance.

These findings support Raharjo and Rachmawati (2026), who reported that HIRADC combined with Job Safety Analysis (JSA) improves hazard identification and supports the development of effective control measures. Similar findings were reported by Suryomukti and Saragih (2024), who stated that HIRADC enables organizations to identify hazards, evaluate risks, and establish preventive strategies.

The results are also consistent with Susanto (2024) and Harum (2024), who emphasized that HIRADC is a fundamental element of Occupational Safety and Health Management Systems (OSHMS) because it integrates hazard identification, risk assessment, and control determination into a structured process.

Furthermore, the effectiveness of hierarchy-based control implementation observed in this study supports Hulu et al. (2025) and Putra et al. (2025), who highlighted that risk control priorities should be determined systematically according to hazard levels and control effectiveness.

Compared with previous studies that mainly focused on manufacturing, construction, and general industrial environments, this research provides additional evidence regarding HIRADC implementation in a high-complexity power generation maintenance environment. The 50,000-hour Major Overhaul of STG involves simultaneous exposure to multiple hazards, including high-pressure systems, electrical equipment, lifting operations, and high-temperature components.

Therefore, this study contributes both practically and academically by demonstrating that HIRADC can be applied as a structured risk management framework for improving occupational safety performance during major maintenance activities in combined-cycle power plants.

CONCLUSION

This study applied the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method to evaluate occupational hazards during the 50,000-hour Major Overhaul of the

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Steam Turbine Generator (STG) at the Tanjung Uncang Combined Cycle Power Plant, PT PLN Batam. The results identified 11 maintenance activities, consisting of 6 High Risk and 5 Medium Risk activities before control implementation. Following the implementation of engineering controls, administrative controls, competency requirements, and personal protective equipment (PPE), all identified risks were successfully reduced to the Low Risk category, indicating that residual risks had reached acceptable levels. These findings demonstrate that the HIRADC method is effective in identifying hazards, evaluating occupational risks, and determining appropriate control measures for complex maintenance activities. Practically, the proposed control measures can support improvements in standard operating procedures, work permit systems, competency development, and periodic HIRADC reviews to strengthen occupational safety performance and maintenance reliability in power generation facilities. Recommendation there is conduct periodic field compliance audits, implement a digital occupational health and safety (OHS) monitoring system, and provide regular refresher training to ensure the consistent implementation of safety controls, real-time monitoring of critical OHS requirements, and continuous improvement of personnel competence in inspection and commissioning activities.Top of FormBottom of Form

REFERENCES

Aji, U., & Santoso, S. (2024). Analysis of TEF Operational Risk Management for Trains and Underground Stations of MRT Jakarta. *East Asian Journal of Multidisciplinary Research*, *3*(9), 4165–4182. Https://doi.org/10.55927/eajmr.v3i9.10573

Ajslev, J. Z. N., Møller, J. L., Andersen, M. F., Pirzadeh, P., & Lingard, H. (2022). The Hierarchy of Controls as an Approach to Visualize the Impact of Occupational Safety and Health Coordination. *International Journal of Environmental Research and Public Health*, *19*(5), 2731. Https://doi.org/10.3390/ijerph19052731

Alshreef, B. S. (2026). Beyond Compliance: An HRO-Based Governance Framework for ISO 45001–Enabled Safety Strategy in Healthcare. *Risk Management and Healthcare Policy*, *Volume 19*, 1–11. Https://doi.org/10.2147/RMHP.S604364

Anshari, L. H., Azkha, N., & Ernawati, T. (2025). Hubungan Unsafe Action dan Unsafe Condition dengan Kecelakaan Kerja di PT X Padang. *Jurnal Kesehatan Komunitas (Journal of Community Health)*, *11*(3), 469–474. Https://doi.org/10.25311/keskom.Vol11.Iss3.2328

Aulia, L., & Hermawanto, A. R. (2020). ANALISIS RISIKO KESELAMATAN KERJA PADA BAGIAN PELAYANAN DISTRIBUSI LISTRIK DENGAN METODE HIRARC (Studi Kasus di PT. Haleyora Power). *Sistemik : Jurnal Ilmiah Nasional Bidang Ilmu Teknik*, *8*(1), 20–27. Https://doi.org/10.53580/sistemik.v8i1.36

Davies, K., Weale, V., & Oakman, J. (2025). A Work Systems Hierarchy of Controls: Analysis of Risk Controls Developed by Paramedics. *American Journal of Industrial Medicine*, *68*(8), 698–710. Https://doi.org/10.1002/ajim.23741

Devira Rona Prisnayanti, & Evi Widowati. (2024). Implementasi Sistem Manajemen Keselamatan dan Kesehatan Kerja di PT X. *Antigen : Jurnal Kesehatan Masyarakat Dan Ilmu Gizi*, *2*(3), 179–191. Https://doi.org/10.57213/antigen.v2i3.330

Fatkhul, S. R., & Dwi Saputri, T. A. (2026). Analisis Implementasi Program Keselamatan dan Kesehatan Kerja dalam Upaya Mengurangi Risiko Kecelakaan Kerja pada PT PLN (Persero) ULP Samarinda Kota. *ULIL ALBAB : Jurnal Ilmiah Multidisiplin*, *5*(6), 1288–1294. Https://doi.org/10.56799/jim.v5i6.17044

Febyola, L., Zainuddin, A., & Muchtar, F. (2025). Analisis Implementasi Keselamatan Dan Kesehatan Kerja (K3) Sebagai Upaya Pencegahan Kecelakaan Kerja Pada Karyawan PT. PLN (Persero) Unit

Copyright © 2026, the author(s). This is an open access article under the CC-BY-SA License.

Layanan Transmisi Dan Gardu Induk (ULTG) Kendari. *KOLONI*, *4*(1), 50–58. Https://doi.org/10.31004/koloni.v4i1.715

Harum, A. P. (2024). Evaluation of the Implementation of the Occupational Safety and Health Management System (SMK3) at Dr. H. Bob Bazar Hospital, Indonesia. *Golden Ratio of Data in Summary*, *5*(1), 01–17. Https://doi.org/10.52970/grdis.v5i1.776

Heronasia, S., & Zuraida, R. (2025). Integrating Occupational Safety and Health Management Systems (SMK3) with Total Quality Management (TQM) in Micro-Scale Manufacturing Enterprises. *Advance Sustainable Science Engineering and Technology*, *7*(4), 0250406. Https://doi.org/10.26877/asset.v7i4.2054

Howay, Y. Y., & Sukwadi, R. (2026). Analisis Kecelakaan Sengatan Listrik pada Shovel di Lingkungan Kerja PT Freeport Indonesia Affiliated Freeport mcmoran. *Jurnal Praktik Keinsinyuran*, *3*(02), 117–124. Https://doi.org/10.25170/jpk.v3i02.7657

Hulu, F. B. T., Asriwati, A., & Nuraini, N. (2025). Evaluation of the Implementation of the Occupational Safety and Health Management System (SMK3). *Journal of Community Health Provision*, *5*(3), 145–162. Https://doi.org/10.55885/jchp.v5i3.773

J. EL- Matury, H., Syahlan, N., Baharuddin, M. R. B., Ginting, E. S. B., Inggrianingsi, I., & Batubara, S. (2025). Implementation of Occupational Safety and Health Management Systems (OSHMS) in Construction: A Comparative Study of Four Sumatra Sites. *Jurnal Kesehatan Komunitas (Journal of Community Health)*, *11*(3), 512–525. Https://doi.org/10.25311/keskom.Vol11.Iss3.2305

Khahro, S. H., Ali, T. H., Hassan, S., Zainun, N. Y., Javed, Y., & Memon, S. A. (2021). Risk Severity Matrix for Sustainable Public-Private Partnership Projects in Developing Countries. *Sustainability*, *13*(6), 3292. Https://doi.org/10.3390/su13063292

Maghfirah, S., Zakwan, M. H., Marpaung, F. A. H., & Hasibuan, A. (2025). Implementation of Safety Management System to Improve Safety Performance of Construction Workers: Literature Review. *AMK : Abdi Masyarakat UIKA*, *4*(2), 105–111. Https://doi.org/10.32832/amk.v4i2.2693

Mayansara, A., Atnang, M., Dwiyanti, D., & Banudi, L. (2025). Risiko Kecelakaan kerja : Perspektif Pegawai terhadap Implementasi Sistem Manajemen Keselamatan dan Kesehatan Kerja. *Health Information : Jurnal Penelitian*, *17*(2), 176–186. Https://doi.org/10.36990/hijp.v17i2.1543

Mulyadin, A., Yusmardono, Bharka, E., & Kasih, T. P. (2025). Analysis of occupational hazards and risks using HIRADC JSA Methods Case Study: Asbestos demolition In Ereveld Menteng Pulo. *IOP Conference Series: Earth and Environmental Science*, *1564*(1), 012070. Https://doi.org/10.1088/1755-1315/1564/1/012070

Putra, V. M., Rusba, K., & Ramdan, M. (2025). ANALISA RISIKO KECELAKAAN KERJA DI RIG JACK UP DENGAN MENGGUNAKAN METODE JOB SAFETY ANALYSIS. *IDENTIFIKASI*, *11*(4), 966–971. Https://doi.org/10.36277/identifikasi.v11i4.756

Raharjo, B. A., & Rachmawati, F. (2026). Risk Analysis of the Solar Power Plant (SPP) Development Project at PLN Nusantara Power Up Gresik. *Journal of Social Research*, *5*(4), 1666–1685. Https://doi.org/10.55324/josr.v5i4.3084

Roebidin, R., Febitya Valent Difiana, Bunga Farida, & Anom Dwi Prakoso. (2025). HUBUNGAN UNSAFE ACTION DAN UNSAFE CONDITION DENGAN KECELAKAAN KERJA PADA PEKERJA BATU ALAM DI DESA CIPANAS DUKUPUNTANG CIREBON. *Indonesian Journal of Health Research Innovation*, *2*(2), 1–10. Https://doi.org/10.64094/6jtabm30

Rusdinah, R., & Tobing, C. N. (2025). Analisis Kecelakaan Kerja pada Pekerja Smelter di PT Indonesia Morawali Industrial Park dalam Perspektif Hukum Ketenagakerjaan. *Jurnal Sosial Dan Sains*, *5*(6), 1760–1776. Https://doi.org/10.59188/jurnalsosains.v5i6.32215

Suhartina, Herni Johan, & Rr. Nindya Mayangsari. (2023). Analisis Manajemen Risiko Keselamatan Kerja Terhadap Ketenagakerjaan di Unit PLTGU Tanjung Batu, Kutai Kartanegara. *Bunda Edu-Midwifery Journal (BEMJ)*, *6*(1), 48–54. Https://doi.org/10.54100/bemj.v6i1.136

Copyright © 2026, the author(s). This is an open access article under the CC-BY-SA License.

Suryomukti, M., & Saragih, Y. (2024). Analisis Risiko di Area Switchyard PT.PLN Gardu Induk Kosambi Menggunakan Metode HIRARC. *Jurnal Energi Baru Dan Terbarukan*, *5*(2), 1–11. Https://doi.org/10.14710/jebt.2024.22625

Susanto, A. (2024). Tinjauan Literatur Sistematis: Identifikasi Bahaya, Penilaian Risiko dan Pengendalian Risiko Pada Operasi Pertambangan. *Jurnal Manajemen Kesehatan Yayasan RS.Dr. Soetomo*, *10*(2), 446. Https://doi.org/10.29241/jmk.v10i2.2065

Syalomita, K., Andino, W., I wayan, D., & Betsi, R. (2023). PATUHI KESEHATAN DAN KESELAMATAN KERJA PADA INSTALASI PEMBANGKIT LISTRIK TENAGA SURYA. *Journal Central Publisher*, *1*(4), 244–252. Https://doi.org/10.60145/jcp.v1i4.78

Theodorou, J. A., & Tzovenis, I. (2024). Risk management in the Greek mussel farming through ISO 31000. *Oceanological and Hydrobiological Studies*, *53*(1), 79–87. Https://doi.org/10.26881/oahs-2024.1.09

Thyroidi Prasojo, R. A., & Jufriyanto, Moh. (2025). PENERAPAN METODE HIRADC DAN JSA UNTUK ANALISIS RISIKO KECELAKAAN KERJA PADA PROSES PENGEPRESAN CUP AIR MINERAL SWA DI PT SWABINA GATRA GRESIK. *INTECOMS: Journal of Information Technology and Computer Science*, *8*(6), 2070–2077. Https://doi.org/10.31539/2dv1zf91

Tiway, Moch. F. H., Ratriwardhani, R. A., Ayu, F., & Sahri, Moch. (2025). Analisis Kecelakaan Kerja pada Divisi Metal Stamping di PT. XYZ Menggunakan Metode Systematic Cause Analysis Technique (SCAT). *Jurnal Keselamatan Kesehatan Kerja Dan Lingkungan*, *6*(2), 167–177. Https://doi.org/10.25077/jk3l.6.2.167-177.2025

Widana, A. K. (2024). IDENTIFIKASI BAHAYA DAN PENILAIAN RISIKO KESELAMATAN DAN KESEHATAN KERJA MENGGUNAKAN METODE HIRARC PADA GARDU INDUK AMPENAN. *Jurnal Informatika Dan Teknik Elektro Terapan*, *12*(3S1). Https://doi.org/10.23960/jitet.v12i3s1.5272

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