

Risk Analysis of Work Accidents Using HIRADC and JSA to Achieve Zero Accident in the Electricity Industry

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Abstract

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Workplace accidents remain a serious problem across industrial sectors because they can lead to severe injuries, fatalities, and material losses. In Indonesia, workplace accident cases reached 356,383 as of October 2024, indicating the urgent need for more effective occupational safety risk control. This research identifies and analyzes occupational safety risks in the electricity industry, which is characterized by potential exposure to chemical, mechanical, ergonomic, and physical hazards. This research integrates Hazard Identification, Risk Assessment, and Determining Control (HIRADC) with Job Safety Analysis (JSA). HIRADC was used to identify, classify, and assess hazard levels across eight work areas, while JSA was applied to examine the most critical activity identified from the risk assessment results. Based on observations, interviews, and company reports in 2024, 498 findings were identified, of which 59% were negative findings caused by unsafe actions and unsafe conditions. The risk recapitulation showed that 76% of potential hazards were classified as high risk, 22% as moderate risk, and 2% as low risk. Area 2 recorded the highest average risk score of 9.20, while Area 4 had the largest number of hazards, with 10 findings and a maximum risk score of 12. Mechanical hazards were the most frequently identified hazard type, accounting for 18 findings, or 42.9% of the total hazards, whereas physical hazards had the highest average risk score of 8.90. The JSA results indicated that generator maintenance was the most critical activity because it involved multiple hazard types, including electrical, mechanical, physical, and chemical hazards. The proposed control measures were formulated based on the hierarchy of controls, particularly administrative controls and personal protective equipment. These findings suggest that integrating HIRADC and JSA can support electricity companies in identifying critical hazards, prioritizing preventive actions, and strengthening occupational safety management toward zero accident performance.

1. INTRODUCTION

Work accidents are a serious issue faced by various industries (Milošević *et al.*, 2025), as they often result in significant injuries, fatalities, and material losses (Dyreborg *et al.*, 2024). Fatal occupational accidents may also result in substantial losses in working hours, financial costs, and overall productivity within companies (Sánchez-Lite *et al.*, 2024). The increase in workplace accident cases may be caused by various factors. One of the main factors is that occupational safety is often insufficiently integrated into operational practices. These aspects include: (a) process design and production equipment; (b) the supply of safety devices; (c) system of reduction, training, and strengthening of occupational hazard and risk mitigation. (Viswanathan *et al.*, 2024). Therefore, to minimize the occurrence of workplace accidents, it is essential to establish an effective Occupational Safety and Health Management System (OSHMS) in every industrial sector (Viswanathan *et al.*, 2024).

The need for an effective Occupational Safety and Health Management System (OSHMS) becomes even more important in industrial sectors with complex operational hazards. One of these sectors is the electricity and energy sector, where workers are exposed to significant risks during power production, transmission, and distribution activities. These

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activities in electricity industry can pose significant risks to workers, including electric shock, burns, and falls (Wong & Meng, 2024). These hazards may result in severe injuries, fatalities, lost workdays, and financial losses if not properly controlled (Sadeghi-yarandi *et al.*, 2023; Wong & Meng, 2024). The urgency of research in the electricity industry is reinforced by data from the Electrical Safety Foundation International (ESFI), which shows 1,654 electrical fatalities in the workplace during 2011–2024. The rate of electrical fatalities has increased relatively during this period, indicating that electrical hazards remain an uncontrolled occupational safety and health (OSH) issue. The largest cause of electrical fatalities is contact with overhead power lines at 42.8%, followed by unintentional contact with electricity at 19.3% and contact with energized equipment around the work area at 12.7%. In addition to fatalities, ESFI also stated that there were 5,180 cases of electrical injuries that caused workers to be absent from work in 2023–2024 (Majano, 2026). Therefore, electrical workplace accidents are a serious problem and require systematic hazard identification, risk assessment, and risk control as essential components of occupational health and safety management in the electricity industry.

Several previous studies have also carried out hazard identification, risk assessment, and risk control systematically using various methods, such as Hazard Identification, Risk Assessment, and Determining Control (HIRADC) and Job Safety Analysis (JSA), as a relevant approach in occupational safety risk analysis. HIRADC refers to the systematic process of identifying hazards associated with both routine and non-routine work activities (Ameliawati, 2022). The HIRADC method is applied because it emphasizes risk control as the primary outcome of the occupational risk analysis process, unlike other methods such as HIRA and HIRARC. In HIRADC, the process does not end with hazard identification and risk assessment, it extends to the selection and implementation of structured and specific control strategies for each work activity. This approach makes HIRADC more comprehensive and operational, as the analysis results are directly utilized as the foundation for establishing Occupational Safety and Health (OSH) objectives and targets, including initiatives to prevent, reduce, and eliminate workplace accidents toward achieving zero accidents. Furthermore, HIRADC explicitly incorporates the hierarchy of control principle, ensuring that the selection of control measures is based on their effectiveness rather than mere procedural compliance. This characteristic distinguishes HIRADC from HIRA, which focuses solely on risk assessment, and from HIRARC, which does not explicitly emphasize control establishment as a strategic foundation for OSH management and the formulation of occupational safety targets (Ananda & Srisantyorini, 2025). The HIRADC assessment process is divided into three stages, namely: (1) hazard identification according to type and type *hazard*; (2) Risk assessment using an occupational safety and health assessment scale matrix (OSH); and (3) risk control based *Hierarchy of Control* (Faizah *et al.*, 2021). Lazuardi *et al* (2022) used the HIRADC method in the Electrical Assembly to identify hazards, assess risks, and determine controls for 18 types of work, with the riskiest jobs being in the cleaning, electrical, and change model technician sections. However, the use of HIRADC in this research still focused on the general work process level, thus not breaking down risky activities into more detailed work stages. A similar approach was also used by Pamungkas *et al* (2025) to identify hazards in switchyard inspection, battery room cleaning, tower inspection, and generator maintenance activities. The research identified several key risks, such as electric shock, chemical exposure, noise, struck by equipment, leakage, and fire. However, the resulting control recommendations were still at the macro activity level and did not explain controls based on a specific sequence of work steps.

Meanwhile, JSA is a qualitative hazard identification method that concentrates on a specific task. JSA plays a role in giving workers an understanding of how a job should be

done (*step by step*) based on the safety procedures and instructions developed (Ghasemi *et al.*, 2023). Oktavia & Fauziah (2025) applied the JSA method to a survey of outdoor internet access installation paths at Biznet Cirendeuh and successfully identified field hazards such as falls from heights, electric shocks, ergonomic injuries, extreme weather, and contact with sharp objects. Although JSA is able to provide a more specific description of hazards at the job level, the research did not present quantitative risk priorities, such as risk scores or the distribution of risk levels between activities. A similar finding was seen in the research by Zainul *et al.* (2025), who applied JSA to electrical panel installation work and identified electric shock, short circuits, and fire as the main risks. Based on this trend, previous studies indicate that HIRADC and JSA have been widely used in occupational safety and health (OSH) risk analysis; however, both methods tend to be applied separately.

HIRADC has the advantage of mapping risks and determining control priorities at the area or work activity level, but is still limited in describing hazards in detail at each work stage. Conversely, JSA is able to provide a more in-depth analysis at the work stage level, but is not always equipped with comprehensive mapping and prioritization of risks between areas or work activities. In developing an effective Occupational Safety and Health (OSH) Management System, it is essential to conduct a comprehensive risk assessment to identify potential hazards in the workplace, thus enabling the formulation of appropriate preventive measures (Van Derlyke *et al.*, 2022). Therefore, this research integrates HIRADC and JSA into a single analytical framework to more comprehensively identify hazards, assess risks, and determine control measures, ranging from area-level risk mapping to a detailed analysis of the most critical work activities. This approach aims to analyze the risk of occupational accidents in the electrical industry and formulate more specific and operational risk controls to support the achievement of zero accidents.

2. METHODOLOGY

This research procedure is structured in stages through seven main processes, namely data acquisition, data preprocessing, HIRADC-based risk assessment, hazard mapping, critical activity selection, Job Safety Analysis, and recommendation and validation as shown in Figure 1.

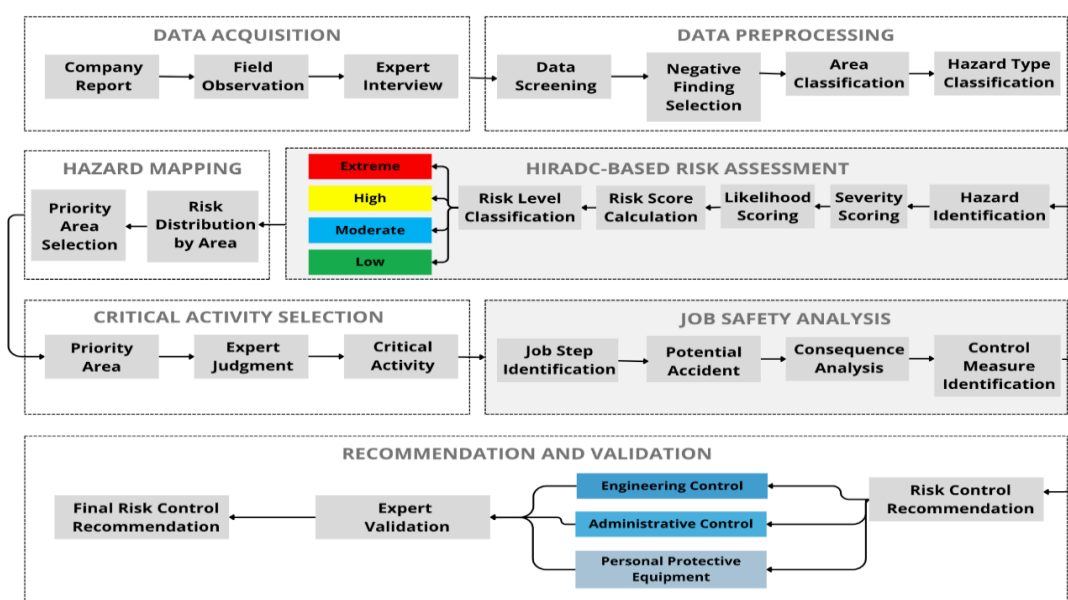


Figure 1.
Data Collection Flow and Recommendations

The research methodology consisted of seven stages: data acquisition, data preprocessing, HIRADC-based risk assessment, hazard mapping, critical activity selection, Job Safety Analysis (JSA), and recommendation validation. Data were collected from company occupational safety and health (OSH) reports, field observations, and interviews with OSH personnel and experts. The collected data were then screened and classified based on work areas and hazard types, including biological, chemical, physical, psychosocial, ergonomic, and mechanical hazards (Hisam *et al.*, 2023). The work environment was divided into eight areas according to the company layout to support hazard mapping and priority area determination. Hazards identified from negative findings were assessed using severity and likelihood scales ranging from 1 to 5, and the resulting risk scores were categorized into low, moderate, high, and extreme levels based on the risk matrix (Atirah *et al.*, 2022).

The risk assessment results were summarized through hazard mapping to identify priority areas with dominant high-risk findings. Based on hazard mapping, expert judgment, field observations, and interviews, generator maintenance activities in Areas 2 and 4 were selected as critical activities for further analysis using JSA. In this stage, work activities were broken down into detailed work steps to identify potential hazards and determine appropriate control measures for each stage. Finally, risk control recommendations were developed based on the hierarchy of controls, focusing on engineering controls, administrative controls, and personal protective equipment (PPE). The recommendations were then validated by experts to ensure their suitability with actual field conditions and company procedures, resulting in more specific and operational controls to support zero-accident efforts in the electricity industry.

3. RESULTS AND DISCUSSION

3.1 Hazard Identification, Risk Assessment, and Hazard Mapping (HIRADC)

Based on company reports and the layout of the electrical industry work area, the work area is classified into eight areas. The first area, symbolized by A1, is the administrative and employee housing work area. Area 2, symbolized by A2, is the gas power plant area. Area 3, symbolized by A3, is the hazardous waste disposal and treatment area. Area 4, symbolized by A4, is the diesel power generation unit area. Area 5, symbolized by A5, is the switchyard area. Area 6, symbolized by A6, is the fuel storage area. Area 7, symbolized by A7, is the gas power generation unit area. Finally, area 8, symbolized by A8, is the WTP and radiator area. This classification was conducted to facilitate hazard mapping, particularly in zones with the highest potential risk.

Each of the eight areas underwent hazard identification based on findings reported in the company's findings report, observations, and interviews. The amount of data analyzed was 498 findings with a percentage of 59% negative findings and 41% positive findings as shown in Figure 2(a). These negative findings were caused by two factors, 95% due to unsafe conditions and 5% due to unsafe actions. After each hazard was identified in the eight areas, the findings were grouped into six types of hazards, namely biological hazards, chemical hazards, physical hazards, ergonomic hazards, and mechanical hazards (Hisam *et al.*, 2023). After that, a risk assessment was carried out by measuring the likelihood and severity levels to be categorized into 4 risk levels, namely low, moderate, high, and extreme, as shown in Table 1.

Table 1.
Risk Matrix

Likelihood	Almost Certain	5	Moderate	Moderate	High	Extreme	Extreme
	Likely	4	Low	Moderate	High	Extreme	Extreme
	Possible	3	Low	Moderate	High	High	Extreme
	Unlikely	2	Low	Low	Moderate	High	Extreme
	Rare	1	Low	Low	Moderate	High	High
			1	2	3	4	5
			Insignificant	Minor	Moderate	Major	Catastrophic
			Severity				

Source : (Atirah *et al.*, 2022) and (Albar *et al.*, 2022)

Table 2.
Risk Assessment of Potential Hazards in the Area of Electrical Industry

Code	Location	Causes of Hazard	Hazard Type	S	L	R	Category
A.12	Building A	Room lighting	Mechanical	1	4	4	Low
A.14	Building C	Office waste pollution	Chemical	2	4	8	Moderate
A.14	Building C	Facility component damage	Mechanical	2	4	8	Moderate
A.14	Building C	Roof/ceiling leaks	Mechanical	2	4	8	Moderate
A.15	Building D	Rat infestation	Biological	3	2	6	Moderate
A.13, A.14	Buildings B and C	Slipping and tripping	Physical	3	2	6	Moderate
A.14	Building C	Electrical short circuit	Mechanical	4	2	8	High
A.16	Motorcycle Parking	Fire risk from smoking	Chemical	4	1	4	High
A.14	Building C	Damaged fire protection system	Mechanical	4	1	4	High
A2.3	Gas Power Plant 3	Working at height	Physical	4	3	12	High
A2.1	Building E	Noise exposure	Mechanical	3	3	9	High
A2.5	Control Room Gas Power Plant	Slipping and tripping	Physical	3	3	9	High
A2.7	Gas Power Plant transformer	Fire risk from hay	Chemical	4	2	8	High
A2.5	Control Room Gas Power Plant	Damaged fire extinguisher	Mechanical	4	2	8	High
A3.2	Diesel Power Plant B	Oil spill contamination	Chemical	3	3	9	High
A3.2	Diesel Power Plant B	Unlabeled gas cylinder	Chemical	3	3	9	High
A3.1	Warehouse	Electrical short circuit	Mechanical	3	3	9	High
A3.1	Diesel Power Plant B	Slipping and tripping	Physical	3	3	9	High
A3.1	Warehouse	Corroded machine parts	Chemical	4	2	8	High
A3.1, A3.2	Diesel Power Plant B and Warehouse	Pipe/hydrant leaks	Mechanical	4	2	8	High
A4.1, A4.3	Diesel Power Plant 200 MW and Gas Power Plant 2	Flammable material leakage	Chemical	4	3	12	High
A4.1	Diesel Power Plant 200 MW	Faulty fire extinguisher	Mechanical	4	3	12	High
A4.3	Gas Power Plant 2	Oil spill	Chemical	3	3	9	High
A4.1	Diesel Power Plant 200 MW	Electrical short circuit	Mechanical	3	3	9	High
A4.1	Diesel Power Plant 200 MW	Slipping and tripping	Physical	3	3	9	High
A4.1	Diesel Power Plant 200 MW	Exhaust impact hazard	Physical	3	3	9	High
A4.7	WTP	B3 waste accumulation	Chemical	2	3	6	Moderate
A4.1	Diesel Power Plant 200 MW	Non-ergonomic work chair	Ergonomic	3	2	6	Moderate
A4.1	Diesel Power Plant 200 MW	Inadequate lighting	Mechanical	2	3	6	Moderate
A4.1	Diesel Power Plant 200 MW	Facility equipment damage	Mechanical	4	2	8	High
A5.1	Switchyard	Slipping and tripping	Physical	3	3	9	High
A5.1	Switchyard	Burn risk from hay	Chemical	4	1	4	High
A6.2	PMK	Infrastructure damage	Mechanical	3	3	9	High
A6.8	HSD Tank	Slipping and tripping	Physical	4	2	8	High
A6.1, A6.8	Transfer Pump and HSD Tank	HSD fuel leakage	Chemical	4	1	4	High
A7.3	Gas Power Plant 5 6	Chemical liquid splashes	Chemical	3	3	9	High
A7.3	Gas Power Plant 5 6	Structural facility damage	Mechanical	3	3	9	High
A7.3	Gas Power Plant 5 6	Slipping and tripping	Physical	3	3	9	High
A7.3	Gas Power Plant 5 6	Incomplete fire extinguisher	Mechanical	4	2	8	High
A7.3	Gas Power Plant 5 6	Unsafe machinery operation	Mechanical	4	2	8	High
A7.3	Gas Power Plant 5 6	Electrical short circuit	Mechanical	3	2	6	Moderate
A8.1	WTP	Slipping and tripping	Physical	3	3	9	High

In assessing risks across the eight work areas shown in **Error! Reference source not found.**, likelihood represents the probability of a hazard occurring based on historical

frequency and future occurrence potential. Likelihood was classified into five levels: rare (1), unlikely (2), possible (3), likely (4), and almost certain (5) (Atirah *et al.*, 2022). Severity describes the worst possible impact of a hazard on worker safety, asset damage, operational disruption, and organizational consequences. Severity was also classified into five levels: insignificant (1), minor (2), moderate (3), major (4), and catastrophic (5) (Albar *et al.*, 2022). These classifications provided a quantitative basis for objective and measurable risk assessment in occupational safety decision-making. Based on the recapitulation results in Figure 2(b), 76% of hazards were classified as high risk, 22% as moderate risk, and 2% as low risk, while no hazards were categorized as extreme risk.

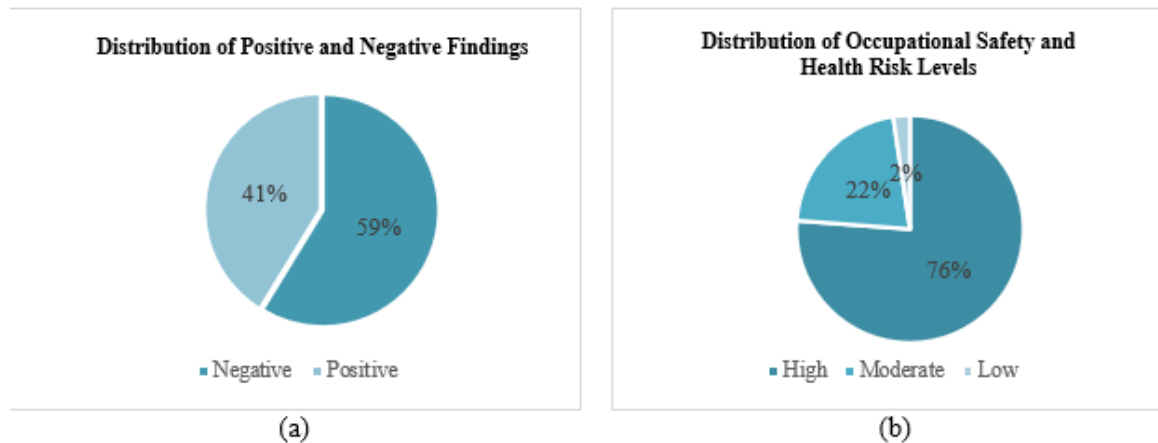


Figure 2.

(a) Distribution of Positive and Negative Findings, (b) Distribution of Occupational Safety and Health Risk Levels

Table 3.

Risk Distribution by Area

Area	Work Area	Total Hazards	Low	Moderate	High	Extreme	High Risk (%)	Average Risk Score	Max Risk Score	Priority Rank
A2	Gas power plant area	5	0	0	5	0	100	9.20	12	1
A4	Diesel power generation unit area	10	0	3	7	0	70	8.60	12	2
A8	WTP and radiator area	1	0	0	1	0	100	9.00	9	3
A3	Hazardous waste disposal and treatment area	6	0	0	6	0	100	8.67	9	4
A7	Gas power generation unit area	6	0	1	5	0	83	8.17	9	5
A6	Fuel storage area	3	0	0	3	0	100	7.00	9	6
A5	Switchyard area	2	0	0	2	0	100	6.50	9	7
A1	Administrative and employee housing area	9	1	5	3	0	33.3	6.22	8	8

Table 4.

Risk Distribution by Hazard Type

Hazard Type	Total Findings	Low	Moderate	High	Extreme	Percentage of Total Findings (%)	Average Risk Score	Max Risk Score	Dominant Area
Mechanical	18	1	4	13	0	42.9	7.83	12	A1
Chemical	12	0	2	10	0	28.6	7.50	12	A3, A4
Physical	10	0	1	9	0	23.8	8.90	12	A2, A4
Biological	1	0	1	0	0	2.4	6.00	6	A1
Ergonomic	1	0	1	0	0	2.4	6.00	6	A4

Risk analysis was conducted by grouping hazards based on work area and hazard type to identify areas with the highest risk concentration and the most dominant hazards. Based on the risk distribution results in Table 3, Areas 2 and 4 were identified as priority areas. Area 2 had the highest average risk score (9.20), with all hazards categorized as high risk, mainly related to power plant activities, noise exposure, falls from heights, transformer fire risks, and fire protection system damage. Meanwhile, Area 4 had the highest number of hazards (10 findings), including seven high-risk hazards with a maximum risk score of 12, indicating a wider variety of risks such as flammable material leaks, damaged fire extinguishers, electrical short circuits, oil spills, slipping hazards, and exhaust component hazards. Therefore, both areas were categorized as critical areas requiring intensive risk control. To support spatial visualization, hazard mapping was developed using Google Earth and Adobe Photoshop, as shown in Figure 3.



Figure 3.
Hazard Mapping Area Electrical Industry

Risk distribution by hazard type (Figure 4) showed that mechanical hazards were the most dominant, accounting for 18 findings (42.9%), mainly related to equipment damage, fire protection system failures, short circuits, and unsafe machinery operations. However, physical hazards had the highest average risk score (8.90), indicating more severe potential impacts, such as falls, slips, trips, and crushing hazards. Chemical hazards also contributed significantly, with 12 findings (28.6%), primarily associated with fuel, oil, hazardous waste, chemical spills, and flammable materials. These findings indicate that risk control priorities should consider both hazard frequency and risk severity, with mechanical hazards requiring attention due to their high occurrence and physical hazards due to their higher risk level.

3.2 Job Safety Analysis and Detection Control

Job Safety Analysis (JSA) is one of the popular techniques used to identify hazards and assess risks in the workplace qualitatively. The JSA specifically concentrates on the hazards created by the tasks performed by workers (Ghasemi *et al.*, 2023). JSA has six benefits: (1) formalization of work, (2) accountability, (3) employee participation, (4) organizational learning, (5) hazard identification and situational awareness, and (6) prevention of losses (Albrechtsen *et al.*, 2019). The types of jobs that are categorized as needing to use JSA to minimize work risks are routine, non-routine, and new jobs (Rajkumar *et al.*, 2021). The

analysis of potential risks obtained from the JSA itself also needs to be given preventive recommendations through the hierarchy of control, which is a way to determine which actions are best to control exposure. The hierarchy of control has five levels of action to reduce or eliminate harm. The sequence of actions based on the effectiveness of prevention in general is: (1) Elimination; (2) Substitution; (3) Engineering Controls; (4) Administrative Control; and (5) PPE as shown in Figure 4 (Jogie *et al.*, 2025).

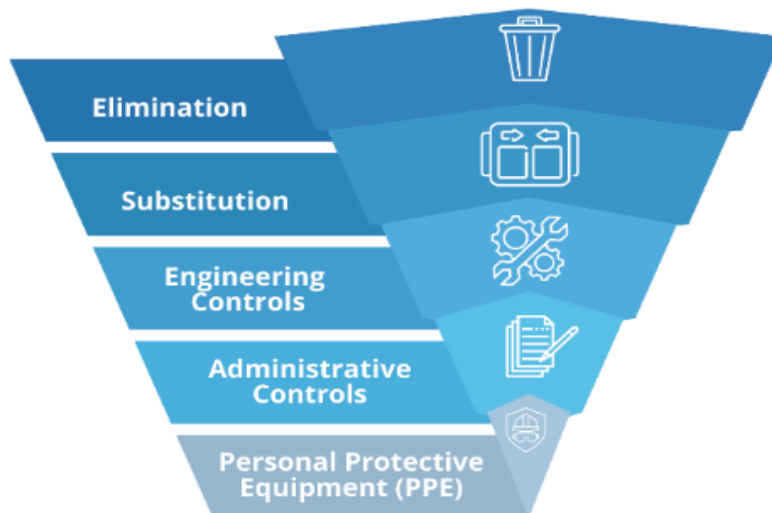


Figure 4.
Hierarchy of Controls

Elimination is the most effective level of control because it permanently removes the source of danger, eliminating the need for further control measures. Based on Jogie *et al* (2025) confirms that elimination provides the most reliable protection because it does not depend on worker behavior or continuous monitoring. This approach is in line with the principle of prevention through design, where hazards are addressed from the design stage of the work system. If elimination is not possible, substitution is carried out by replacing hazardous materials, processes, or work methods with alternatives that have a lower level of risk. Substitution is effective because it reduces the level of danger at the source and decreases dependence on administrative controls and PPE. Engineering controls are a form of control that focuses on physical modifications to equipment, facilities, or work systems in order to separate workers from sources of danger. This approach is considered more reliable than administrative controls because its effectiveness does not depend on individual behavior.

In the electrical industry, as shown in Table 2, hazards such as electrical short circuits, flammable material leaks, oil spills, pipe or hydrant leaks, and exhaust-related hazards can be effectively controlled through engineering controls. These include electrical insulation and grounding systems, secondary containment and drip trays, ventilation systems, and machine guarding. Engineering controls provide long-term protection, reduce accident rates, and improve operational stability. Administrative controls, also shown in Table 2, reduce risk through work procedures, policies, and supervision, including SOPs, permits to work, job rotation, and rest breaks, particularly for hazards such as noise exposure. The implementation of relevant job rotation can help balance workload distribution through periodic worker movement between workstations, thereby reducing and distributing worker energy and noise exposure more evenly (Mura & Dini, 2023). Furthermore, regulating rest breaks through work/rest schedules also plays a role in preventing the accumulation of

muscle fatigue (Lee *et al.*, 2022). Battini *et al* (2022) also developed a multi-objective job rotation scheduling model that simultaneously considers several socio-technical factors, including noise and vibration exposure risks, fatigue and recovery, and flexible rest break planning. The study demonstrated that job rotation and rest time management not only function as work schedule management but also as a human-centric approach to managing ergonomic risks, work environment exposure, and worker recovery needs. However, their effectiveness depends on worker compliance and supervision, so they should be combined with higher-level controls. PPE serves as the final layer of protection against residual risks such as electric shock, chemical splashes, noise exposure, working at height, and exhaust hazards. As presented in Table 2, common PPE includes safety helmets, insulated gloves, protective eyewear, hearing protection, safety harnesses, and safety shoes. Effective PPE implementation requires proper training, regular inspection, and integration with other controls.

Based on the hazard mapping results in Figure 3 and the risk distribution shown in Table 3, Areas 2 and 4 were identified as the most critical areas due to their higher potential risks compared to other areas. Therefore, the analysis continued by selecting the highest-risk work activities in these two areas for further detailed analysis using Job Safety Analysis (JSA). The selection of critical activities was based on risk distribution results, field observations, and interviews with HSE experts within the company. The validation results indicated that generator maintenance activities in Gas Power Plant Units 3 and 4 and the Diesel Power Plant, performed by the maintenance division, had the highest potential risk in Areas 2 and 4. These activities were selected because they involve a combination of electrical, mechanical, physical, and chemical hazards within a single work process, thus requiring more detailed analysis at the work-step level.

Generator maintenance activities were divided into six main tasks: preparation of special tools, generator uncoupling, generator rotor pull-out, winding cleaning, electrical assessment, and generator coupling. The Job Safety Analysis was conducted through direct observation of workers from the Electrical Maintenance division responsible for generator maintenance activities, as presented in Tables 5–10.

Table 5.

Job Safety Analysis (JSA) Generator Maintenance Preparation Stage Tools

No	Job Description	Potential Hazard	Hierarchy of Hazard Control	Risk Control Description
1	Material and equipment mobilization	Hit by falling/heavy materials	AC	Mechanical lifting required
		Tripping during mobilization	AC	Clear mobilization path
		Injury from sharp equipment	PPE	Safety shoes and gloves
2	Tool and sliding beam fabrication	Hot metal splash or debris	PPE	Welding PPE required
		Poor air circulation	AC	Adequate ventilation
		Contact with operating machine	AC	Safe operating distance
3	Equipment installation	Pinched by heavy equipment	AC	Proper installation secured
		Electrical shock	PPE	Full PPE required
		Damaged or exposed power cable	AC	Electrical condition inspection

Description: Elimination = E; Substitution =S; Engineering Control = EC; Administrative Control = AC; and Personal Protective Equipment = PPE

Table 6.**Job Safety Analysis (JSA) Maintenance Generator Stage Uncouple Generator**

No	Job Description	Potential Hazard	Hierarchy of Hazard Control	Risk Control Description
1	Flywheel/coupling cover opening	Falling material	AC	Approved tools only
		Injury from sharp tools	AC	Stable work area ensured
2	Alignment pre-check	Pinched by measuring tools	PPE	Full PPE required
			AC	Tool condition verified
3	Flywheel web deflection inspection	Falling material	PPE	Full PPE required
			AC	Stable work area ensured
4	Coupling bolt and spacer removal	Metal splashes	PPE	Eye and hand protection
		Injury from sharp tools	AC	Stable work area ensured

Description: Elimination = E; Substitution =S; Engineering Control = EC; Administrative Control = AC; and Personal Protective Equipment = PPE

Table 7.**Job Safety Analysis (JSA) Maintenance Generator Job Pull Out Rotor Generator**

No	Job Description	Potential Hazard	Hierarchy of Hazard Control	Risk Control Description
1	Visual inspection	Dust or debris exposure	AC	Clean work area
			PPE	Dust protection PPE
2	Generator cover removal	Electrical shock	AC	Power isolation required
		Falling material	PPE	Approved tools only
3	Power and control cable disconnection	Electrical shock	AC	Power isolation required
			PPE	Full PPE required
4	Electrical pre-cleaning check (IR & PI)	Electrical shock	AC	Power isolation required
			PPE	Full PPE required
5	Air gap measurement	Pinched by equipment	PPE	Approved tools only
6	Bolt and shim removal	Metal splashes	AC	Tool condition verified
		Injury from sharp edges	PPE	Hand and eye protection
7	Labyrinth dismantling (DE & NDE)	Falling material	AC	Stable work area ensured
			PPE	Full PPE required
8	Generator jacking	Falling or struck by load Fall from height	AC	Approved lifting equipment
			PPE	Body harness required
			AC	Safety barrier installed
9	Bearing dismantling	Fire from oil or grease	AC	Spill control prepared
10	Pedestal bearing dismantling	Falling material	AC	Stable work area ensured
		Fire from oil or grease	AC	Spill control prepared
11	Rotor extension installation	Pinched or overrun Fall from height	AC	Approved lifting equipment
			PPE	Body harness required
			EC	Safety barrier installed
12	Stator sliding and rotor pull-out	Crushed by rotor Fall from height	AC	Approved lifting equipment
			PPE	Body harness required
			EC	Safety barrier installed
13	Pre-cleaning visual inspection	Dust or debris exposure	AC	Clean work area
			PPE	Dust protection PPE

Description: Elimination = E; Substitution =S; Engineering Control = EC; Administrative Control = AC; and Personal Protective Equipment = PPE

Table 8.**Job Safety Analysis (JSA) Generator Maintenance Cleaning Winding Stage**

No	Job Description	Potential Hazard	Hierarchy of Hazard Control	Risk Control Description
1	Dry cleaning	Dust or debris exposure	PPE	Dust protection PPE
		Electrical shock	AC	Equipment isolation verified
2	Wet / dry ice cleaning	Chemical exposure	PPE	Chemical-resistant PPE
		Dry ice frostbite	AC	Avoid direct contact
			EC	Adequate ventilation ensured
3	Drying (heating)	Burns from overheating	PPE	Heat-resistant PPE
		Hot steam exposure	AC	Safe distance maintained
4	Red oxide varnishing	Toxic chemical exposure	PPE	Respirator and gloves
		Chemical vapor inhalation	EC	Adequate ventilation ensured
5	Conductive paint application	Toxic chemical exposure	PPE	Respirator and gloves
		Chemical vapor inhalation	EC	Adequate ventilation ensured

Description: Elimination = E; Substitution =S; Engineering Control = EC; Administrative Control = AC; and Personal Protective Equipment = PPE

Table 9.**Job Safety Analysis (JSA) Generator Maintenance Electrical Assessment Stage**

No	Job Description	Potential Hazard	Hierarchy of Hazard Control	Risk Control Description	
1	Winding resistance measurement	Electrical shock	AC	Power isolation required	
			PPE	Full PPE required	
2	IR & PI testing	Electrical shock	AC	Power isolation required	
			PPE	Full PPE required	
3	Partial discharge calibration	Electrical shock	AC	Power isolation required	
			PPE	Full PPE required	
4	Partial discharge measurement	Electrical shock	AC	Power isolation required	
			PPE	Full PPE required	
5	Tan delta and capacitance testing	Electrical shock	AC	Power isolation required	
			PPE	Full PPE required	
6	NLIBA testing	Electrical shock	AC	Power isolation required	
			PPE	Full PPE required	
7	RSO / drop test	Electrical shock	AC	Power isolation required	
			Falling material	AC	Approved tools only
				PPE	Full PPE required
8	Wedges coil inspection	Falling material	AC	Stable work area ensured	
			PPE	Full PPE required	

Description: Elimination = E; Substitution =S; Engineering Control = EC; Administrative Control = AC; and Personal Protective Equipment = PPE

Table 10.**Job Safety Analysis (JSA) Maintenance of Couple Generator Stage Generator**

No	Job Description	Potential Hazard	Hierarchy of Hazard Control	Risk Control Description
1	Alignment	Pinched by tools	AC	Tool condition verified
			PPE	Full PPE required
2	Fixed labyrinth seal replacement	Pinched by tools	PPE	Full PPE required
3	Temperature detector replacement	Pinched by tools	PPE	Full PPE required
4	Electrostatic air filter replacement	Pinched by tools	PPE	Full PPE required
5	Silicon diode replacement	Pinched by tools	PPE	Full PPE required
6	Varistor module replacement	Pinched by tools	PPE	Full PPE required
7	Coupling bolt and spacer installation	Metal splashes	AC	Approved tools only
		Injury from sharp tools	PPE	Hand and eye protection
8	Flywheel web deflection check	Falling material	AC	Stable work area ensured
			PPE	Full PPE required
9	Flywheel/coupling cover installation	Falling material	AC	Approved tools only
			PPE	Full PPE required

Description: Elimination = E; Substitution =S; Engineering Control = EC; Administrative Control = AC; and Personal Protective Equipment = PPE

Based on the Job Safety Analysis results in Tables 5–10, the recommended controls for generator maintenance activities were primarily engineering controls, administrative controls, and personal protective equipment (PPE). This is because the identified hazards, such as electric shock, entrapment during rotor handling, chemical vapor exposure, and falls in confined areas, are inherent to generator maintenance activities. Therefore, elimination and substitution controls were not feasible, as these activities are essential to power plant operations and constrained by technical specifications and safety standards. Similar findings by Jogie *et al* (2025) indicate that in high-risk industrial maintenance work, engineering, administrative, and PPE controls are often the most practical and effective approaches.

Engineering controls, including safety barriers and ventilation systems, were prioritized because they directly reduce hazard exposure and do not rely on worker behavior. Safety barriers help prevent contact with hazardous machine components and improve safety system reliability (Husnaseptia *et al.*, 2024). Ventilation systems reduce exposure to chemical vapors and airborne contaminants during cleaning and coating processes (Ejaz *et al.*, 2024). Administrative controls, such as power isolation, work permits, and restricted access, were applied to minimize operational errors and uncontrolled exposure. Gonyora & Ventura-medina (2024) stated that permit-to-work is an important part of a safe work system because it functions as a formal system for controlling potentially hazardous work. Papersonline *et al* (2022) also emphasized that Lockout/Tagout (LOTO) is a procedure that significantly reduces the risk of workplace accidents by isolating and securing energy sources in industrial equipment. Personal protective equipment (PPE) is the final layer in the risk control hierarchy, including helmets, gloves, safety glasses, respirators, safety shoes, and safety harnesses. PPE is used to reduce worker exposure to hazards during maintenance activities. The use of PPE becomes relevant when engineering and administrative controls are not feasible or have not been effective in reducing risk to an acceptable level. Therefore, PPE is used to control residual exposures that remain after other risk controls have been implemented (Vukicevic *et al.*, 2022). Together, these controls help reduce risks to acceptable levels while maintaining operational continuity.

3.3 Implication and Limitation

This research contributes to occupational safety and health (OSH) risk analysis by integrating HIRADC and JSA into a hierarchical framework. HIRADC was used to identify, assess, and prioritize risks at the work-area level, while JSA provided detailed hazard analysis at the work-step level. This integration strengthens risk analysis by linking macro-level risk assessment with micro-level hazard identification. These findings can support companies in prioritizing risk control in critical areas, particularly Areas 2 and 4, through improved inspections, supervision, maintenance, and safe work procedures. The JSA results for generator maintenance also provide practical guidance for developing operational risk controls based on engineering controls, administrative controls, and personal protective equipment (PPE) to support zero-accident efforts. However, this research is limited by the absence of post-implementation evaluation, potential subjectivity in risk assessment, and its focus on a single electricity industry unit. Future research should evaluate the effectiveness of implemented controls and expand the study to multiple generating units for broader comparison and validation.

4. CONCLUSION

Based on field observations, interviews, and company reports, this research identified 498 findings, of which 59% were negative findings related to unsafe acts and unsafe conditions in the electrical power industry. Most hazards were classified as high risk (76%),

followed by moderate (22%) and low risk (2%), indicating substantial exposure to operational hazards. HIRADC analysis across eight work areas identified Area 2 (Gas Power Plant Units 3 and 4) and Area 4 (200 MW Diesel Power Plant) as the most critical areas. Area 2 had the highest average risk score (9.20), with all hazards categorized as high risk, while Area 4 recorded the highest number of hazards, including seven high-risk hazards with a maximum risk score of 12. Mechanical hazards were the most frequent category (42.9%), followed by chemical (28.6%) and physical hazards (23.8%). However, physical hazards had the highest average risk score (8.90), indicating a greater severity level despite occurring less frequently.

Based on the HIRADC results, hazard mapping, and expert validation, generator maintenance was selected for further Job Safety Analysis (JSA) due to its association with multiple hazard categories, including electrical, mechanical, physical, and chemical risks. The JSA identified significant hazards during tool preparation, generator separation, rotor pull-out, winding cleaning, electrical assessment, and generator coupling, including electric shock, entrapment, falling objects, working at height, exposure to dust or chemical vapors, and mechanical injuries. Since elimination and substitution controls were not feasible, risk mitigation focused on engineering controls, administrative controls, and personal protective equipment (PPE). PPE remained an essential additional protection layer against residual risks such as electric shock and hazardous material exposure. Overall, the findings indicate that occupational hazards in the electricity industry remain predominantly high risk, highlighting the importance of consistent risk control implementation. However, this research was limited to a single operational setting and relied mainly on observational and interview-based data. Future studies should involve multiple facilities and integrate quantitative risk modeling to evaluate the long-term effectiveness of safety controls and support zero-accident performance in the electricity sector.

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