

Dealing with Occupational Health and Safety Practices Using JSA with HIRARC Method

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Abstract

Occupational Health and Safety (OHS) remains a pressing issue in high-risk environments, where incidents such as electric shocks and falls. The PLN Ampenan Substation, a critical facility within Lombok's power distribution network, poses serious risks to workers' safety. To address the issues, the study investigates the application of the Job Safety Analysis (JSA) method to identify workplace hazards and assess their effectiveness in reducing accidents. This study employs a combination of JSA and HIRARC (Hazard Identification, Risk Assessment, and Risk Control) frameworks to address prevalent hazards involving exposure to high-voltage equipment and working at elevated positions. The implementation of JSA enabled the development of practical control measures, including improved use of Personal Protective Equipment (PPE), better compliance with safety protocols, and structured risk mitigation plans. This study not only reinforces the role of JSA in enhancing workplace safety but also serves as a reference for improving OHS practices in similar high-risk electrical installations.

Keywords:

OHS, JSA, HIRARC, Risk Assessment

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1. Introduction

In 2021, there were 234,370 reported occupational accidents with 6,552 fatalities, representing a 5.7% increase from the previous year[1] This alarming statistic highlights the urgent need to strengthen and improve the effectiveness of OHS systems, particularly in high-risk work environments such as electrical installations[2]. The Ampenan Substation, a critical component of PT PLN (Persero)'s electricity distribution network in Lombok Island, faces significant hazards including electric shocks, falls from height, and exposure to hazardous chemicals[3]

Similar conditions have been reported in other substations across Indonesia. For instance, a study at Teluk Kuantan Substation found that ineffective PPE use and limited supervision significantly increased safety risks [4][5][6]Consequently, a method capable of systematically mapping and evaluating risks measurably and practically is required [7]. JSA offers a systematic breakdown of work steps to identify potential hazards and develop appropriate preventive measures Recent research indicates that JSA effectively reduces workplace accidents when combined with routine risk assessments. For example, in oil tank welding at Pertamina's SP Ogan Field, the implementation of JSA significantly minimized work-related hazards[8]. Its participatory nature directly involves workers, enhancing their awareness and adherence to safety protocols [9].

To complement and strengthen risk evaluation, this study combines JSA with the widely recognized HIRARC method. HIRARC is chosen as a standard method because it systematically classifies hazards based on work activities and quantitatively assesses risks by integrating two key parameters: likelihood and severity [10]. Moreover, it provides a

hierarchical framework for risk control, ranging from hazard elimination, substitution, engineering controls, and administrative controls, to the use of PPE, ensuring a comprehensive and measurable approach to risk management [11].

This study constructs OHS model at the Ampenan Substation using the JSA to enable a thorough examination of HIRARC with data from the Indonesian Workers Social Security Agency (BPJS Ketenagakerjaan). The novelty of this research is the integration of JSA and HIRARC methods in a high-voltage working environment while previous studies have applied JSA in general industrial or construction settings. This study incorporates primary data gathered through field observations and interviews to enable a realistic and contextual understanding of workplace conditions. It also proposes practical risk control strategies applicable to similar distribution units and contributes significantly to the development of participatory and quantitative OHS systems. Therefore, the findings are expected not only to improve safety standards but also to serve as a reference for implementing OHS facilities.

2. Related Works

A study proposed the implementation of JSA during welding activities in the oil and gas sector to identify workplace hazards and enhance compliance with safety procedures. The application of JSA involved measures such as the use of PPE, structured worker training, and routine inspections, which effectively minimized risks during welding operations. The study emphasized how aligning JSA with the ISO 45001 Risk Control Hierarchy could improve hazard mitigation effectiveness [12]. Another work evaluated the use of the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method in an electrical assembly department to manage occupational risks. Through interviews and observations, it was found that cleaning and electrical technicians faced the highest exposure to risks. Recommendations included improving PPE availability, increasing OHS awareness programs, and installing additional safety signage to reduce medium-level risks [8].

An article examined the application of JSA to identify potential hazards in the digester and press stations. The research uncovered various risks such as oil spills causing slippery floors and noncompliance with PPE usage among workers. It concluded that low OHS awareness and poor maintenance practices contributed to unsafe working conditions, necessitating stricter supervision and enforcement of safety policies. Another study utilized the HIRARC method to assess risks in the construction of a university business center. The study identified 18 potential hazards categorized from low to extreme risk. Risk mitigation measures included technical controls, elimination strategies, administrative regulations, and the provision of additional PPE. Regular meetings and visual warnings were also recommended to raise safety awareness among workers [13].

Another study conducted at a palm oil processing plant applied the JSA framework to improve OHS outcomes. The method facilitated structured hazard recognition across different stations, such as digesters and clarifiers, identifying high-risk scenarios involving hot machinery and residual waste. The findings emphasized the importance of involving workers in the hazard identification process to foster a proactive safety culture [14]. Another research conducted at a fabrication workshop in a steel construction company applied both the JSA and the HIRARC methods to evaluate and mitigate occupational risks. The analysis covered high-risk activities such as welding, grinding, cutting, and assembling. The results revealed multiple hazards categorized as extreme and high risk, particularly in welding and grinding processes. By integrating JSA to break down each job step and applying HIRARC to assess the likelihood and severity of hazards, the study demonstrated that this combined approach is effective in identifying risks and determining appropriate control measures. The findings highlighted the importance of structured risk assessment in

reducing workplace accidents and improving overall safety performance in industrial environments [4]. This study explores the combination of JSA and HIRARC methods in reducing workplace accidents with comprehensive safety protocols, active worker participation, and technological support.

3. Proposed Method

This study adopts a descriptive qualitative method aimed at presenting a systematic and factual overview of the implementation of OHS through the JSA approach at the Ampenan Substation. This approach was chosen because it provides the researcher with the flexibility to explore in depth the processes of hazard identification, risk evaluation, and control measures implemented by technicians in their daily work activities [11]. We conducted this study at PT PLN (Persero) Electricity Service Unit, Ampenan, located in Mataram City, West Nusa Tenggara in 2024. The objects of the study include three main types of high-risk tasks: circuit breaker operation, transformer maintenance, and routine inspection. The subjects consist of five technicians who have direct experience with these activities. Data collection techniques include observation, interviews, and documentation. We undergo observations to identify potential hazards and to document the implementation of OHS measures [15], interviews with technicians using semi-structured interviews [9], and collecting data such as SOPs and JSA forms [16]

Data analysis refers to the JSA and HIRARC methods which the JSA process involves identifying each step of the observed tasks, determining the potential hazards at each stage, and formulating appropriate control actions[17]. Technician involvement is considered essential to enhance awareness of workplace safety[18]. Risk assessment using the HIRARC method was carried out by calculating risk scores based on two parameters: likelihood and severity[19]. The risk value was determined by multiplying these two parameters, and the results were categorized into four levels: extreme, high, medium, and low[20]. This classification then served as the basis for selecting appropriate risk control strategies[21].

Through the combination of JSA and HIRARC approaches, this study aims to provide a comprehensive overview of the effectiveness of OHS implementation at the Ampenan Substation[22][23]. This process was carried out with the primary goal of minimizing the level of occupational accident risk through a systematic and structured approach. The research followed a well-planned series of stages, with all activities scheduled in detail in a timetable, covering the entire research process—from literature review and methodological implementation to final evaluation and examination stages[24][25].

Table 1. Job Safety Analysis

No	Activity Stage	Potential Hazards	Risks	Control Measures
1	Vehicle movement in and out of the project site	- Fatal traffic accidents - Being hit or hitting others	- Being hit or hitting - Fatalities	- Emergency signs required - Adjust route access - Dump truck must be covered
2	Community Outreach	- Miscommunication	- Causing unrest - Injuries	- Provide complete and interactive information

3	Scaffold installation	<ul style="list-style-type: none"> - Unbalanced scaffold position - Unstable scaffold - Inappropriate installation area 	<ul style="list-style-type: none"> - Falling - Hit by falling objects - Electric shock 	<ul style="list-style-type: none"> - Work according to procedure - Ensure scaffold material is proper - Use appropriate PPE - Mark live electrical areas
4	Mobilization of equipment and machinery	<ul style="list-style-type: none"> - Overloading - Unfit vehicles 	<ul style="list-style-type: none"> - Hit by vehicle - Fall from vehicle - Being crushed 	<ul style="list-style-type: none"> - Inspect vehicle before use - Work according to procedure - Drive following traffic rules
5	Equipment inspection	<ul style="list-style-type: none"> - Unfit equipment - Installation damage - Operation failure 	<ul style="list-style-type: none"> - Tower collapse - Injuries - Fatalities 	<ul style="list-style-type: none"> - Equipment check - Work according to procedure - Use tools according to standard - Ensure PPE is used
6	Placing Puller & Tensioner	<ul style="list-style-type: none"> - Incorrect placement - Operation failure 	<ul style="list-style-type: none"> - Tower collapse - Equipment damage 	<ul style="list-style-type: none"> - Team coordination - Use PPE - Work according to procedure - Place equipment on hard ground
7	Setting Puller & Tensioner	<ul style="list-style-type: none"> - Instruction error - Inadequate ground strength 	<ul style="list-style-type: none"> - Tower collapse - Injuries - Damage 	<ul style="list-style-type: none"> - Place on hard ground - Certified operator - Equipment check before use
8	Unclamping conductor	<ul style="list-style-type: none"> - Live electricity - Work at height - Inadequate safety condition - Instruction error 	<ul style="list-style-type: none"> - Electric shock - Fall from height 	<ul style="list-style-type: none"> - Install grounding stick - Use full PPE - Toolbox meeting before work
9	Releasing conductor clamp	<ul style="list-style-type: none"> - Live electricity - Work at height - Inadequate safety condition - Instruction error 	<ul style="list-style-type: none"> - Electric shock - Fall from height 	<ul style="list-style-type: none"> - Ensure the grounding stick installed - Use full PPE - Toolbox meeting before work
10	Prall tower	<ul style="list-style-type: none"> - Live electricity - Work at height - Inadequate safety condition - Instruction error 	<ul style="list-style-type: none"> - Electric shock - Fall from height 	<ul style="list-style-type: none"> - Ensure the grounding stick installed - Use full PPE - Toolbox meeting before work
11	Conductor pulling	<ul style="list-style-type: none"> - Live electricity - Work at height - Inadequate safety condition - Instruction error 	<ul style="list-style-type: none"> - Electric shock - Fall from height 	<ul style="list-style-type: none"> - Ensure the grounding stick installed - Use full PPE - Toolbox meeting before work
12	Midspan jointing conductor	<ul style="list-style-type: none"> - Live electricity - Work at height - Inadequate safety 	<ul style="list-style-type: none"> - Electric shock - Fall from height 	<ul style="list-style-type: none"> - Ensure the grounding stick installed - Use full PPE

		condition - Instruction error		- Toolbox meeting before work
13	Sagging	- Live electricity - Work at height - Inadequate safety condition - Instruction error	- Electric shock - Fall from height	- Ensure the grounding stick installed - Use full PPE - Toolbox meeting before work
14	Jumper	- Live electricity - Work at height - Inadequate safety condition - Instruction error	- Electric shock - Fall from height	- Ensure the grounding stick installed - Use full PPE - Toolbox meeting before work
15	Clamping	- Live electricity - Work at height - Inadequate safety condition - Instruction error	- Electric shock - Fall from height	- Ensure the grounding stick installed - Use full PPE - Toolbox meeting before work

Table 2. Categories of Hazard

Level	Description	Categories
1	Rare	Very unlikely to occur
2	Unlikely	Rarely occurs
3	Possible	Occasionally occurs
4	Likely	Frequently occurs
5	Almost Certain	Almost always occurs

Table 3. Severity of Hazard

Level	Description	Details
1	Insignificant	Does not cause physical injury, has minimal economic loss, and only causes mild health disturbances without serious risks.
2	Minor	Minor injuries, small financial loss, and may cause mild illness.
3	Moderate	Moderate injuries that may require medical treatment, cause significant financial loss and can lead to moderately severe illness.
4	Major	Serious injuries affect more than one person, major financial loss and production disruption, and cause severe illness.
5	Catastrophic	Causes severe illness or death, with multiple casualties. Resulting in a very large economic loss and a complete operational shutdown of the company.

Table 4 Risk assessment matrix-Level of risk

Likelihood of Hazard	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Rare (1)	L	L	M	H	H
Unlikely (2)	L	L	M	H	E
Possible (3)	L	M	H	E	E
Likely (4)	M	H	H	E	E
Almost Certain (5)	H	H	E	E	E

4. Result and Discussion

1. Dataset

The Ampenan Substation is one of the critical components of the electrical system on Lombok Island, serving as a link between the transmission network and the primary distribution system. This facility is equipped with various high-voltage equipment, such as circuit breakers, transformers, disconnectors, and other protective devices. Due to the operational complexity and the high voltage used, this location presents significant occupational hazard potentials.

2. Method

The application of the JSA method is conducted to examine the stages of work at the substation, identify potential hazards, and determine appropriate control measures. Based on observations and interviews with technicians, the highest hazard potentials were found in activities such as operating circuit breakers, transformer maintenance, and routine inspections. These hazards include electric shocks, slipping while working at heights, fires due to short circuits, and injuries caused by left-behind tools.

Table 5. Equipment at Ampenan Substation

INDOOR	OUTDOOR
Switchgear Room	Current Transformer (CT)
Battery Room	Busbar Disconnector (PMS) 1/2
	Line Disconnector (PMS)
	Neutral Grounding Resistor (NGR)
	Station Service Transformer (PS)
	Circuit Breaker (CB)
	Lightning Arrester (LA)
	Voltage Transformer (VT)
	Power Transformer

3. Identification

We used the HIRARC to assess the risk levels associated with each potential hazard identified during the JSA process. This assessment was based on two main parameters: likelihood (the probability of the hazard occurring) and severity (the seriousness of the impact). The calculated risk scores were then categorized into four levels: low, medium, high, and extreme. Most occupational risks identified fell within the medium to high

categories, particularly in activities involving high-voltage equipment and tasks conducted outdoors under extreme weather conditions.

Based on observations and interviews at the Ampenan Substation, various potential hazards were found throughout the work processes, especially during circuit breaker operation and transformer maintenance. This study classified two specific activity stages as extreme risk due to the possibility of electric shock, while inspection activities were rated as high risk because of potential fire hazards. Activities such as tool preparation and housekeeping were categorized as medium risk. We also gathered primary dataset to measure workers' understanding, perception, and compliance with OHS practices with the JSA and HIRARC. The questionnaire distributed to five technicians revealed that the majority understood the importance of hazard identification and risk assessment before starting work. 100% of respondents indicated increased discipline in the use of PPE following training and supervision driven by the risk assessment outcomes.

4. Risk Level Assessment

The HIRARC method is a systematic approach used to identify hazards, assess risks based on the likelihood of occurrence and potential impact, and determine appropriate control measures to mitigate those risks. This method is highly relevant in high-risk work environments, such as electrical installations at the Ampenan Substation, to minimize accidents and enhance occupational safety.

The next step in the HIRARC method is the risk assessment process, which aims to evaluate the hazard level of each previously identified work activity. After potential hazards at the Ampenan Substation are inventoried using the JSA method, a quantitative analysis is carried out using the parameters of likelihood (probability of occurrence), severity (level of impact), and a risk matrix to systematically determine the risk level. The results of this evaluation gathered through questionnaires and interviews with workers and relevant personnel, are then presented in the form of a risk assessment table, which serves as the basis for recommending appropriate control measures.

In the formulation of the HIRARC framework, risk assessment is carried out using the following mathematical formula:

$$R = L \times S \tag{1}$$

- L (Likelihood) represents the probability of a hazard occurring, with a scale ranging from 1 (rare) to 5 (almost certain).
- S (Severity) represents the level of severity resulting from the hazard, with a scale ranging from 1 (insignificant) to 5 (catastrophic).
- R (Risk) is the risk score used as the basis for classifying and determining control measures.

The product of these two parameters determines the risk level, categorized as follows:

Table 6. Risk Assessment Matrix

Risk Score	Risk Category	Control Action
1–2	Low	Acceptable risk, basic control is sufficient
3	Medium	Manageable risk, and standard control required
4	High	Immediate intervention and continuous monitoring

5	Extreme	Immediate action: hazard elimination, LOTO, full PPE
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In this study, we used the HIRARC method to evaluate risks associated with work activities at the Ampenan Substation. Each identified hazard through JSA was assessed based on two main parameters: Likelihood (probability of occurrence) and Severity (level of impact). Both parameters were assigned values on a scale from 1 to 5 according to predefined criteria. For example, during the power shutdown phase, the activity was assigned a Likelihood value of L = 1 (likely to occur) and a Severity value of S = 5 (potential to cause fatal injury or death). The risk score was calculated using the formula:

$$R = L \times S = 1 \times 5 = 5 \quad (2)$$

Based on the risk classification, a score of 5 falls into the Extreme risk category. Therefore, this activity requires strict and immediate risk control measures, such as implementing Lock Out Tag Out (LOTO) procedures, full use of PPE, and specialized training for technicians.

Table 7. JSA of Circuit Breaker Operation at Ampenan Substation

No	Activity Stage	Potential Hazard	Risk	Control
1	Tool preparation	Non-functional or damaged tool	Injury due to damaged equipment	Inspect equipment condition
2	Power disconnection and area marking	Negligence in power disconnection	Severe electric shock	Turn off power, install warning signs
3	Circuit breaker operation	Contact with high-voltage equipment	Serious injury/electric shock	Use complete PPE
4	Work result inspection	Sparks/fire	Fire, equipment damage	Thorough post-work inspection
5	Tidying and storing tools	Tools left behind/in a hazardous position	Injury due to unattended tools	Ensure safe tool storage

Table 8. Risk Assessment of Circuit Breaker Operation using HIRARC

No	Activity Stage	Potential Hazard	Likelihood	Severity	Score
1	Tool preparation	Damaged tool	1	3	Medium
2	Power disconnection	Electric shock	1	5	Extreme
3	Circuit breaker operation	Electric shock	1	5	Extreme

4	Work result inspection	Sparks/fire	1	4	High
5	Tidying tools	Injury from unattended tools	1	3	Medium

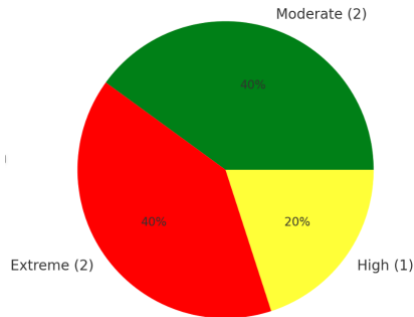


Fig. 1 Circuit Breaker Operation Diagram

The HIRARC method for conducting an assessment of circuit breaker operations identifies electric shock during power disconnection and breaker operation as the most critical hazards, each categorized as Extreme risk due to high severity despite low likelihood. Work result inspection poses a High risk from potential sparks or fire, while tool preparation and tidying are Medium-risk activities related to minor injuries. As shown in Fig. 1, 40% of tasks fall under Extreme, 20% High, and 40% Medium risk categories, indicating that control efforts should focus primarily on stages involving direct electrical contact.

Table 9. Job Safety Analysis of Transformer Maintenance at Ampenan Substation

No	Activity Stage	Potential Hazard	Risk	Control
1	Preparation of tools and PPE	Damaged or uncalibrated tools	Minor injuries, measurement errors	Inspect tools, use PPE
2	Power shutdown	Live current during work	Electric shock, fatal injuries	LOTO procedure, current verification
3	Transformer physical inspection	Hot contact/high voltage	Burns, physical injuries	Insulated gloves, eye protection
4	Transformer area cleaning	Dust, oil, chemicals	Skin irritation/death	Masks, body protection
5	Transformer testing	Wrong connection, electrical arc	Shock, fire	Double check connections, complete PPE

Table 10. Risk Assessment of Transformer Maintenance using HIRARC

No	Activity Stage	Potential Hazard	Likelihood	Severity	Score
1	Tool preparation	Non-standard tools	1	3	Medium
2	Power shutdown	Electric shock	1	5	Extreme

3	Transformer testing	Electrical arc	1	5	Extreme
4	Cleaning	Oil leakage	1	3	Medium
5	Without PPE	Burns	1	5	Extreme

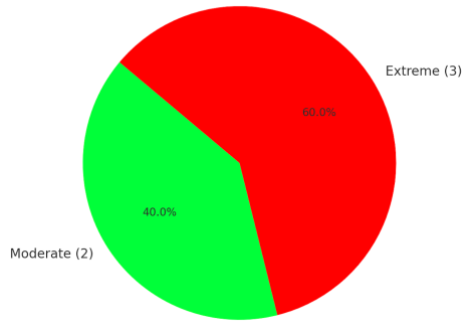


Fig. 2 Transformer Maintenance Diagram

The risk assessment of transformer maintenance activities shows that three out of five stages are classified as Extreme risk, namely: power shutdown, transformer testing, and working without PPE. Meanwhile, tool preparation and cleaning are categorized as Medium risk, associated with equipment issues and chemical exposure. As illustrated in Fig. 2, 60% of the activities fall under Extreme risk, while the remaining 40% are Medium, emphasizing the critical importance of enforcing PPE compliance and safe electrical handling procedures during transformer maintenance.

Table 11. JSA for Routine Transformer Maintenance at PLN Ampenan Substation

No	Activity Stage	Potential Hazard	Risk	Control
1	Preparation before heading to the substation	Slipping, falling	Minor/moderate injuries	Use PPE, check the path
2	Substation area inspection	Tripping, ladder fall	Head/bone injury	Clean the area, use a safe ladder
3	Electrical equipment inspection	Injuries	Burns, serious injuries	Turn off current, test tools, insulating PPE
4	Ventilation inspection	Harmful gases	Shortness of breath, fatigue	Ensure ventilation, use the respirator
5	Tidying work area	Scattered tools	Slipping, injury	Check tools, ensure tidiness

Table 12. Risk Assessment of Routine Substation Inspection using HIRARC

No	Activity Stage	Potential Hazard	Likelihood	Severity	Score
1	Heading to substation	Slipping	1	3	Medium

2	Surrounding area	Tripping	1	3	Medium
3	Equipment inspection	Injuries	1	4	High
4	Ventilation inspection	Poor air quality	1	3	Medium
5	End of work	Scattered tools	1	2	Low

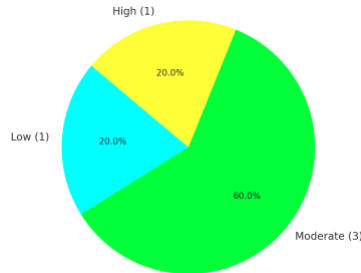


Figure 3. Routine Substation Inspection Diagram

The HIRARC assessment of routine substation inspection indicates that most activities fall under the medium risk category, including risks of slipping, tripping, and poor air quality. Only equipment inspection is classified as High risk due to the possibility of electric shock, while the end-of-work stage presents a Low risk, associated with scattered tools. Fig.3 depicts that 60% of the activities are medium risk, 20% High, and 20% Low, highlighting that while the overall inspection process is relatively safe.

5. Demonstration Results

We implement a demonstration of safety procedures utilizing JSA and HIRARC involving five technicians at the Ampenan Substation using sequential steps, including tool preparation, power shutdown, equipment operation, and post-operation inspection. Observations indicated that most technicians correctly executed fundamental procedures, such as proper use of PPE and adherence to lock-out/tag-out (LOTO) protocols. However, two technicians initially faced challenges in accurately using voltage measuring instruments, which were subsequently addressed through direct instructor guidance.

Post-demonstration questionnaires revealed unanimous responses of "Never" concerning procedural understanding and compliance with safety measures. This finding underscores the necessity for enhanced training programs to improve technician competency and safety awareness. The demonstration provided valuable insight into current technician capabilities in safety procedure implementation and informed the development of more effective training and supervision strategies to strengthen OHS practices on-site.

6. Risk Control

Risk control is the final stage in the HIRARC method, aimed at minimizing potential losses due to workplace accidents by implementing appropriate control measures. Protecting workers from injury and exposure to workplace hazards is a crucial aspect of occupational safety. For example, wearing a mask when entering a battery room prevents the inhalation of toxic gases, thereby significantly reducing potential health risks to workers. Engineering controls are preventive measures designed to isolate workers from hazards through the installation of warning signs or effective hazard visualizations. This application aims to enhance workers' situational awareness and reinforce the overall safety system.

This Elimination approach focuses on the direct removal of hazards and is considered the most effective method in the risk control hierarchy. For instance, during maintenance activities at the substation, all equipment must be ensured to be in a zero-energy state to create a completely safe working environment and minimize the risk of workplace accidents. The Substitution and Material Control involves replacing high-risk materials or equipment with safer and more environmentally friendly alternatives. For example, transformer oil should be replaced regularly to maintain optimal insulation performance and prevent overheating, which could lead to fire hazards. Administrative control refers to non-technical interventions that focus on managing worker behavior and interaction with the work environment. This includes the establishment of standard operating procedures, structured work schedules, and shifts, job rotation to reduce fatigue and boredom, as well as regular implementation of OHS training programs to improve awareness, competence, and work efficiency.

5. Conclusion

This study deals with OHS issues through JSA with HIRARC methods to establish a safe and controlled working environment at the PLN, Ampenan Substation. The application of the HIRARC method had a significant impact on the effectiveness of hazard control strategies. Workers also reported heightened awareness of workplace hazards after actively participating in the risk identification process. The implementation of HIRARC not only reduced the potential for workplace accidents but also strengthened the safety culture within the substation environment.

Quantitative evaluations using the parameters of likelihood and severity provided a structured classification of risks, which informed the implementation of control strategies. The findings also emphasize that the active involvement of technicians in the risk identification process plays a crucial role in fostering a participative and sustainable safety culture. Therefore, the integration of JSA and HIRARC is proven effective in reducing workplace accidents and is highly recommended as a model for OHS implementation in high-risk environments, particularly within electrical installations. Future work may include the development of a digital-based hazard identification and control system, the integration of real-time monitoring tools, or the application of predictive analytics using historical safety data.

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