Analysis Of Occupational Safety And Health (OSH) Implementation And Identification Of Workplace Risks In Live-Line Work On The 20 KV Distribution Network

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Abstract

Live-line work on 20 kV distribution networks is a high-risk activity performed on live, energized lines without power outages. This study analyzes the implementation of Occupational Safety and Health (K3) and identifies occupational risks in live-line work at PLN UP3 Pematangsiantar using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method with the AS/NZS 4360 risk matrix, as well as an Occupational Safety and Health Management System (SMK3) evaluation checklist based on Government Regulation No. 50 of 2012. Data collection was conducted through field observations and structured interviews during the replacement of the Phase R Support Insulator Pin on May 18, 2026, involving a PDKB team of 8 experienced personnel. The results of the OSHMS checklist evaluation showed an OSH implementation score of 100% out of 20 evaluated items across the four elements of Government Regulation No. 50/2012. Hazard identification through a Job Safety Analysis (JSA) identified 11 work stages with 9 potential hazards. The HIRARC assessment identified 3 hazards with a High risk level (risk score = 10)—namely, contact with live conductors, arc flash, and live voltage during line cover removal—as well as 6 hazards with a Medium risk level. No hazards in the “Extreme” category were identified, confirming the effectiveness of the existing occupational safety and health (K3) system, supported by a zero-accident track record over the past two years. Risk control recommendations include improving communication between K3 supervisors and Live-Line Work personnel, as well as strengthening the documentation of periodic PPE inspections.

***Keywords**:* Live-Line Work, K3, HIRARC, Risk Identification, 20 kV Distribution Network, SMK3, AS/NZS 4360

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Introduction

The electric power system is a vital infrastructure that supports modern society and industrial sustainability. In the operation of the electric power distribution system, network maintenance activities are an unavoidable necessity. Live-line work serves as a solution for maintaining the 20 kV distribution network without having to shut down the power supply, thereby ensuring the continuity of supply to consumers[1][2] . The nature of work performed directly on live lines (live line working) makes live-line maintenance one of the most hazardous tasks in the electric power sector. Risks such as electric shock, burns from arc flashes, and falls from heights are real threats that can occur at any time if Occupational Safety and Health (OSH) procedures are not implemented correctly and consistently[3][4] .

Occupational Safety and Health (OSH) regulations in Indonesia comprehensively govern the obligation to implement workplace safety in the electricity sector. Government Regulation No. 50 of 2012 on the Occupational Safety and Health Management System (SMK3) requires every company to systematically identify hazards, assess risks, and establish risk controls[5][6] . Law No. 30 of 2009 on Electricity and PUIL 2011, as the national technical standard for electrical installations, also serve as legal foundations that must be adhered to in the execution of PDKB work[7] . Although regulations are in place, the implementation of OSH in the field—particularly in Live-Line Work work—still requires in-depth and periodic evaluation to ensure compliance with applicable standards.

The Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method is a systematic approach recommended by OHSAS 18001 and adopted in Government Regulation No. 50/2012 for occupational risk assessment[8] . This method enables the comprehensive identification of potential hazards, the assessment of risk levels using a quantitative matrix, and the determination of appropriate control measures based on the hierarchy of risk control. Several previous studies have applied HIRARC to PDKB operations and identified 15 high-category potential hazards at Live-Line Work sites in Central Java[9] . Human error was found to be the primary cause of accidents, and the average SMK3 implementation score was 78% at PLN's Live-Line Work units, with the main weakness lying in documentation[10] . These studies indicate variations in the level of OSH implementation across units, making a specific study of PLN UP3 Pematangsiantar necessary.

This study aims to: (1) analyze the implementation of OSH in Live-Line Work operations at PLN UP3 Pematangsiantar using a checklist based on Government Regulation No. 50/2012; (2) identify potential hazards through a Job Safety Analysis (JSA); and (3) assess risk levels using the HIRARC method with the AS/NZS 4360 risk matrix. The research results are expected to provide an objective overview of the OSH conditions for PDKB work in the field and serve as a reference for other PLN units in their efforts to improve workplace safety.

2. Literature Review and Problem Statement

2.1 Live-Line Work

Live-line work refers to electrical power grid maintenance work carried out while the grid is still energized. The live-line work methods used by PLN on 20 kV distribution networks include three main methods: the Distance Method, which uses an insulated pole (hot stick); the Contact Method, in which workers wear full insulated PPE and come into direct contact with the conductor; and the Potential Method, in which workers operate at the same potential as the conductor[11][12] . Each method has different procedures and PPE requirements in accordance with IEC 60900 for hand tools and IEC 60832 for live-line tools[13][14] . Live-Line Work requires specific competency certification for all personnel involved, in accordance with

Ministry of Energy and Mineral Resources Regulation No. 12 of 2021 [12]. Live-Line Work team must consist of at least one certified Live-Line Work supervisor, a Live-Line Work operator, and support personnel[15][16] .

2.2 Hazard Identification, Risk Assessment, and Risk Control (HIRARC)

HIRARC is a systematic method for identifying potential hazards, assessing the magnitude of risk, and establishing control measures for a given task. This method consists of three stages: (1) Hazard Identification uses a Job Safety Analysis (JSA) to identify all potential hazards at each stage of the work; (2) Risk Assessment determines the magnitude of risk by multiplying the Likelihood (L) and Severity (S) values using the standard 5×5 risk matrix specified in AS/NZS 4360 [13]; and (3) Risk Control, which establishes control measures based on the hierarchy of elimination, substitution, engineering controls, administrative controls, and the use of PPE in accordance with Government Regulation No. 50/2012 [3]. Risk level categories based on the L×S value are: Low (1–3), Medium (4–9), High (10–15), and Extreme (16–25).

2.3 Personal Protective Equipment (PPE) for Live-Line Work

PPE for Live-Line Work work is specifically designed to protect workers from the hazards of 20 kV medium-voltage electric shocks and arc flash hazards. According to IEC 60479-1, direct contact without PPE at a voltage of 20,000 V with a body impedance of 1,500 Ω results in a fatal current of 13.333 mA, far exceeding the ventricular fibrillation threshold of 50–80 mA[17] . Live-Line Work PPE standards refer to IEC 60900 and IEC 61482. Mandatory PPE must include: Class 2 insulated gloves (test voltage 20,000 V, leakage current ≤12 mA); arc-resistant clothing with an ATPV of ≥8 cal/cm²; a Class E safety helmet with a face shield; dielectric insulated footwear; and a safety harness and lanyard for work at heights[18][19] .

3. Methodology

3.1 Research Design and Type

This study employs a descriptive-analytical approach using qualitative methods. The type of research conducted is applied research, which aims to analyze real-world conditions in the field and generate data-driven recommendations. A qualitative approach was chosen because the focus of the study is a deep understanding of the conditions surrounding OSH implementation and the identification of contextual risks, which requires interpretation of behavior and work procedures in the field and cannot be reduced to mere numbers [6]. The researcher acted as an observer and data recorder without directly intervening in the work of the PDKB.

3.2 Data Collection Instruments and Techniques

Data collection was conducted using five complementary instruments. First, the OSH Implementation Observation Sheet covered four aspects: (a) the completeness and condition of 9 types of PPE; (b) the availability, condition, and certification of 7 types of Live-Line Work equipment; (c) compliance with 10 aspects of OSH procedures, ranging from safety briefings to safety debriefings; and (d) the condition of 6 aspects of the work environment, including weather, pole height, and traffic density. Second, the Structured Interview Guidelines—with 8 questions for Supervisors, 7 for Operators, and 7 for Safety Officers—cover work procedures, PPE condition, OSH training, incident records, and improvement plans. Third, a JSA Worksheet to break down Live-Line Work tasks into specific stages and identify potential hazards at each stage along with existing controls. Fourth, the HIRARC Risk Assessment Form, which includes a 5x5 risk matrix based on AS/NZS 4360 to assess the Likelihood (L) and Severity (S) of each identified hazard [13]. Fifth, the OSH Evaluation Checklist consists of 20 items based on Government Regulation No. 50/2012 covering the four elements of the OSH

Management System (SMK3), with response options of Yes, No, and Partially. The secondary data collected included PLN's 2019 PDKB SOP, equipment certification documents and personnel competency records, as well as applicable OSH regulations.

3.3 Data Validity

Data analysis was conducted in stages following the HIRARC procedure, which refers to AS/NZS 4360 and the risk control hierarchy outlined in Government Regulation No. 50/2012. The first stage, Hazard Identification, uses a JSA worksheet to systematically outline all stages of Live-Line Work, identify all potential hazards and risks that may occur, and document existing controls based on observation and interview results.

The second stage, Risk Assessment, evaluates each hazard using two parameters. The Likelihood (L) value is assigned on a scale of 1–5 based on actual field conditions, taking into account existing controls, the team's level of experience, and the zero-accident track record. The Severity (S) value is assigned on a scale of 1–5 based on the theoretical severity of the impact of a 20 kV electrical hazard, in accordance with IEC 60479-1 [14]. The risk level is calculated as $R = L \times S$ and classified as: Low (1–3), Medium (4–9), High (10–15), and Extreme (16–25). The third stage involves evaluating the implementation of SMK3 using a 20-item checklist covering the four elements of Government Regulation No. 50/2012, with the implementation percentage calculated as $P(\%) = (\text{items met} / \text{total items}) \times 100\%$. All analysis results are interpreted descriptively and compared with previous studies to assess the relative position of the PLN UP3 Pematangsiantar PDKB unit.

4. Results and Discussion

4.1 Field Observation Results: PPE and Equipment

The results of observations during the Live-Line Work on May 18, 2026, showed that all 9 types of mandatory PPE were fully available to the PLN UP3 Pematangsiantar PDKB team, including Class 2 insulated gloves, outer protective gloves, arc-resistant clothing, Class E safety helmets, face shields, safety goggles, dielectric insulated shoes, safety harnesses with safety ropes, and safety vests. All 7 types of Live-Line Work work equipment (hot sticks, line covers, insulated ladders, live-line clamps, voltage detectors, insulated ropes, and grounding sets) were available in good condition and certified. Based on an interview with the Supervisor, the equipment is calibrated at the PLN Testing Laboratory in Semarang once a year, and routine inspections are conducted every Friday by the Occupational Safety and Health (K3) Supervisor. This demonstrates full compliance with equipment certification requirements in accordance with IEC 60900.

4.2 Results of the SMK3 Checklist Evaluation

The evaluation of OSH implementation using a checklist based on Government Regulation No. 50/2012 across the four elements of the OSH Management System resulted in a score of 100% out of the 20 items evaluated. The detailed results for each element are presented in Table 1.

Table 1. Summary of SMK3 Checklist Evaluation Results Based on Government Regulation No. 50/2012

No	SMK3 Element	Total Items	Yes	No	% Implementation
1	OSH Policy (Element 1)	3	3	0	100%
2	Occupational Safety and Health Planning (Element 2)	4	4	0	100%

3	Implementation of Occupational Safety and Health (Element 3)	8	8	0	100%
4	Occupational Safety and Health Monitoring & Evaluation (Element 4)	5	5	0	100%
	TOTAL	**20**	**20**	**0**	**100%**

This 100% OSH compliance rate is higher than the findings of Sari et al. [9], who reported an average of 78% at other PLN Live-Line Work units. This achievement is supported by several factors: (1) safety briefings are conducted twice on every workday—in the morning with the UP3 Manager and at the work site; (2) all personnel hold valid competency certifications and have completed training in P2K3, HIRARC, JSA, and Work Permits; (3) the work permit system is consistently applied to every PDKB task; and (4) a mechanism for reporting incidents to the UP3 OSH department is in place and functioning. These findings indicate that the OSH culture at PLN UP3 Pematangsiantar is well-established, in line with the zero-accident target that has been successfully maintained for at least the past two years.

4.3 Hazard Identification through Job Safety Analysis (JSA)

The JSA analysis for the "Replacement of Phase R Support Insulator Pins" task identified 11 work stages, each with its own potential hazards. The identified stages include: preparation and safety briefing, inspection of PPE and equipment, issuance of a work permit, mobilization to the site, installation of safety barriers, checking the line voltage, installation of the cover line, the main PDKB work (hot stick/hand-to-line), removal of the cover line, dismantling of safety barriers, and reporting and documentation. Of these 11 stages, the main Live-Line Work stage involves three potential hazards simultaneously—arc flash, falls from heights, and electric shock—making it the most critical stage in the entire work sequence.

4.4 HIRARC Risk Assessment

The results of the risk assessment using the AS/NZS 4360 HIRARC matrix for the 9 identified potential hazards are presented in Table 2.

Table 2. Results of the HIRARC Risk Assessment for Live-Line Work

No	Work Stage	Potential Hazard	L	S	L×S	Risk Level
1	Preparation & safety briefing	Lack of understanding of SOPs; personnel are unprepared	2	3	6	**Medium**
2	PPE Inspection	PPE is damaged or does not meet standards	1	5	5	**Medium**
3	Checking the line voltage	Voltage detector not working	1	4	4	**Medium**
4	Installation of the cover line	Accidental contact with a live conductor	2	5	10	**High**
5	Live-Line Work Main Activities	Arc Flash	2	5	10	**High**
6	Live-Line Work Main Operations	Fall from a pole	2	4	8	**Medium**

7	Live-Line Work Main Activities	Electric shock	1	5	5	**Medium**
8	Cover line release	Voltage remains active during release	2	5	10	**High**
9	Mobilization / demobilization	Traffic accidents	3	3	9	**Medium**

The HIRARC assessment results show the following risk distribution: 3 hazards with a High level (L×S = 10) and 6 hazards with a Medium level (L×S = 4–9). No hazards were found in the Extreme (L×S ≥ 16) or Low (L×S ≤ 3) categories. The three hazards rated as High are all related to direct work on a 20 kV live power line, namely: (1) accidental contact with a conductor during cover line installation (L=2, S=5); (2) arc flash during primary Live-Line Work (L=2, S=5); and (3) live voltage during cover line removal (L=2, S=5). A Severity score of 5 (Catastrophic) for these three hazards reflects the potential for fatality due to direct contact with 20 kV voltage, which produces a fatal current of >13,000 mA in an unprotected human body.

A Likelihood value of 2 (Unlikely) for these three "High" hazards reflects actual field conditions where controls are effectively in place: full PPE is used, certified hot sticks and cover lines are employed, full supervisory oversight is maintained during work, and procedural briefings are conducted before work begins. This value is lower than the conditions assumed by Hidayat and Nugroho [8] for units with higher rates of human error. The risk of traffic accidents (mobilization) has a Likelihood (L) of 3 (Possible) because external factors involving other drivers on the highway cannot be fully controlled, even though safety barriers and warning signs have been installed. Control recommendations for the three "High" hazards refer to the hierarchy of controls in Government Regulation No. 50/2012: (1) ensure a minimum 30 cm overlap in the installation of the cover line and perform a double verification before contacting the conductor; (2) maintaining a minimum safe distance of 60 cm from live conductors and ensuring arc-flash protective clothing is in serviceable condition; and (3) performing a voltage check before cover line removal begins and ensuring all personnel are in a safe position.

4.5 Challenges and Areas for Improvement

Although OSH compliance reached 100% and the zero-accident track record was maintained, two areas were identified as needing improvement based on the interview results. First, the comfort of PPE: Live-Line Work operators stated that wearing a full set of PPE felt hot, especially in hot weather. This situation has the potential to reduce PPE compliance in the long term if not addressed by providing more ergonomic PPE or scheduling work for cooler times of the day. Second, regarding communication, the Safety Officer identified that communication between the OSH Supervisor and PDKB operators needs to be improved as an area for future enhancement.

Conclusion

This study analyzed the implementation of OSH and identified occupational risks in PDKB work at PLN UP3 Pematangsiantar using the HIRARC method and the SMK3 checklist under Government Regulation No. 50/2012. Based on the research results, three main conclusions can be drawn. First, the evaluation of the SMK3 checklist across the four elements of Government Regulation No. 50/2012 yielded an OSH implementation score of 100% out of the 20 evaluated items. This achievement is higher than the average reported by other PLN PDKB units, which stands at 78%, supported by a two-stage briefing system, certified personnel, consistent work permits, and periodic inspections of PPE and equipment. A zero-accident track record over the past two years confirms the effectiveness of the current OSH system.

Second, hazard identification through a Job Safety Analysis (JSA) identified 11 work stages with 9 potential hazards. The HIRARC assessment identified 3 "High" level hazards (L×S = 10)—conductor contact, arc flash, and live voltage during disconnection—as well as 6 "Medium" level hazards. All three High-level hazards are related to stages involving direct contact with active 20 kV power lines, which theoretically produce a fatal current of >13,000 mA without PPE.

Third, two areas for improvement are the comfort of PPE to reduce the potential for long-term non-compliance, and communication between the OSH Supervisor and Live-Line Work personnel. Further research is recommended to include a multi-site analysis of PLN's Live-Line Work operations in North Sumatra to obtain a more comprehensive picture, as well as the development of a behavioral safety-based OSH culture assessment tool to complement system-based evaluations.

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