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Reducing Risks in Maintenance of High-Voltage Transmission Lines

Nuttanicha Panich and Jittra Rukijkanpanich
Department of Industrial Engineering
Faculty of Engineering, Chulalongkorn University
Bangkok, Thailand
nuttanicha.mn@gmail.com, jittra.r@chula.ac.th

Abstract

The objective of this research was to reduce the risks associated with the maintenance operations of high-voltage transmission lines, which covers Preventive maintenance (PM), Corrective maintenance (CM), and enhancement of transmission system equipment (Improvement maintenance; IM). Considering that the task involves numerous steps and requires teamwork of approximately 8-12 individuals per operation, any errors in execution could result in injuries, fatalities, or repercussions on the electricity supply, potentially causing widespread power outages. The study was conducted with an emphasis on risk management and Job Safety Analysis (JSA) based on the PEME (People-Equipment-Material-Environment) principle. Then, tasks with medium to high-level risks were further assessed using the Failure Mode and Effect Analysis (FMEA) to identify preventive measures or risk control methods, ensuring that the risks were either prevented or kept within the organization's acceptable range. The results from this research provided insights into risk management practices for high-risk tasks based on risk assessments, facilitating the reduction of losses in human resources, assets, and the electricity production process. This, in turn, reduces the chance of missed opportunities in power distribution within the operational unit. It was also found that a work with a high severity value has a small chance of being conceived. Risk can be decreased to an acceptable level for 19 jobs within the organization. In this regard, there are 7 new procedure manuals and improved operating procedures.

Keywords
Transmission system, High-Voltage, Risk Assessment, FMEA, Maintenance

1. Introduction

High-voltage power line maintenance refers to the care and upkeep of power transmission lines, electric distribution lines, substations, or other equipment essential for electricity transmission or distribution. This ensures that the transmission system remains reliable and trustworthy, meeting the needs of customers and maximizing their satisfaction. The high-voltage power lines of the Electricity Generating Authority of Thailand (EGAT) are akin to the major arteries of the Thai electrical system, necessitating consistent maintenance to ensure stability and readiness to provide electricity to all areas of Thailand. A single point of failure or damage can result in widespread power outages. The voltage levels of these high-voltage transmission lines include 69, 115, 230, 300 (HVDC), and 500 kilovolts. Dedicated units are responsible for maintaining the transmission system, ensuring its constant operability. High-voltage power line maintenance tasks, such as Preventive Maintenance (PM), Corrective Maintenance (CM), and Improvement Maintenance (IM), aim to maintain the system's reliability and trustworthiness, maximizing customer satisfaction. Maintenance activities might be conducted while high-voltage electricity is being supplied (Hotline) or after the power has been turned off (Deadline). Regardless of the approach, every operation poses risks at every moment, which can lead to potential losses for the organization. The electrical insulators have been changed, as illustrated in Figure 1. (Alexander et al. 2023) While the High Voltage Transmission Line Maintenance Unit crew is

shutting down faulty electricity (Dead line Maintenance). Given that high-voltage power lines are bare electrical lines, they can discharge electricity to objects without direct contact. Being within the voltage range alone can pose dangers. The higher the voltage, the further the electricity can jump to objects, making it extremely hazardous and potentially fatal. Analyzing risks to reduce dangers associated with operations in maintaining high-voltage electrical systems is one strategy to minimize losses within the unit. Above all, human-related losses must be prevented or if they occur, must be minimized. It's essential to analyze the risks associated with every operational step. If the risk analysis doesn't encompass every step and implement comprehensive control measures, it could lead to significant losses.

Figure 1. Characteristics of transmission line equipment repair work performed while high voltage power is turned off (Deadline Maintenance)

Statistics indicate that each accident results in losses in terms of human resources, assets, and the production process. These losses stem from both controllable and uncontrollable factors, Losses that can be controlled must undergo a risk analysis, hazard identification, and risk assessment that points out all potential dangers that might arise during operations, both for the operators and others involved. It is crucial to determine appropriate control measures before commencing work to ensure that the task remains within the acceptable risk threshold set by the organization, whether it is a minor risk, an acceptable risk, or a moderate risk. When an accident or incident occurs, it results in losses in terms of personnel, assets, and the production process. There is a need to restore the process to ensure services return to normal. Efficient management is crucial to ensure the fastest possible recovery with minimal impact on the business. Therefore, a loss control system is used for analysis and assessment to identify potential future risks. The goal is to ensure that the level of risk remains within acceptable limits of the Metropolitan Region of the Transmission Line Maintenance Department from January 1, 2020, to December 31, 2022, categorized by cause.

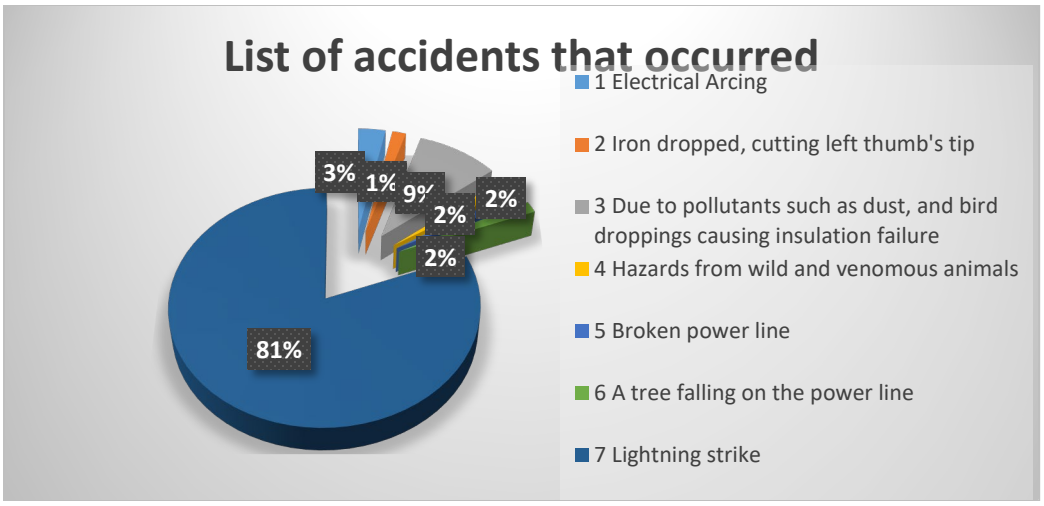

Figure 2. Loss statistics due to accidents in terms of assets and personnel occurring in the operational area

From Figure 2. Statistics on accidents that have occurred are displayed. According to the graph, 81% of accidents were caused by broken electrical wires, followed by pollution such as dust particles and bird droppings leading insulators to lack insulation at 9% and electric shock at 3%, respectively. Steel was the accident item with the lowest rate of occurrence (1%) and was cutting the left thumb's tip.

1.1 Objectives

This research aims to reduce the risk that will affect the maintenance process of high-voltage transmission lines. Covers preventive maintenance (Preventive Maintenance; PM.), correction of electrical transmission system equipment (Corrective Maintenance; CM), and improvement of transmission system equipment (Improvement Maintenance; IM) of the transmission system. To keep the risk level at an acceptable level To achieve the objectives, the Participatory approach principle was applied by experts from the Electricity Generating Authority of Thailand to participate in the risk analysis. and PEME risk analysis and FMEA equipment failure analysis.

2. Literature Review

2.1 Job Safety Analysis: JSA

The principle of Job Safety Analysis is to identify potential hazards or accidents that might occur in each part of a task or operation. The main goal is to prevent these accidents from happening. (Rajkumar et al. 2021) The most knowledgeable person about the job steps should conduct the analysis. The process of Job Safety Analysis comprises 4 steps: (Ghasemi et al. 2023)

Step 1: Selecting the job to be analyzed.
Step 2: Sequencing the job steps appropriately.
Step 3: Identifying potential hazards in each step.
Step 4: Determining the correct and safe methods of working and how to mitigate any identified hazards

2.2 The PEME system

The PEME system is a part of the Integrated Management System (IMS), implemented by the Electricity Generating Authority of Thailand. Its primary objective is to ensure that top executives and managers at all levels within the organization lead, take responsibility, and actively participate in the areas of quality, safety, occupational health, and environment. The system is designed with comprehensive standards for managing various facets, which include ISO9001, MOC's requirements 18001/OHSAS18001(Reniers,2014), and the 14001 requirements.(Arocena et al. 2023) This system collates and indicates potential hazards, routinely and non-routinely, along with risk assessment practices. It encompasses risk evaluations related to machinery operations, equipment, materials, chemicals, operational procedures, on-site personnel, contractors, and stakeholders within the organization's scope of responsibility. The system aids in defining appropriate control measures for operations (Table 1-Table 3). Consideration should be given to analyzing hidden dangers in sub-steps and pinpointing these hazardous sources in the PEME. (Rachel,2017)

Table 1. Meaning of P-E-M-E

P	People
E	Equipment, Machine, Tool
M	Material
E	Environmental

Hazard Likelihood refers to the evaluation based on data from hazard indications that point to equipment failures and errors from work practices. It considers the probability of these incidents occurring. The likelihood is categorized into three levels: high, moderate, and low.

Table 2. Rating for Severity (Fekri et al. 2023)

Severity Level	Rating	Effect on Personal Injury	Effect on Property Value	Effect on Production and Power Supply Process
High	3	- Death - Permanent disability - Loss of limb - Work stoppage for more than 20 days	- More than 500,000 Baht	Power outages exceeding 100 MW
Moderate	2	- Work stoppage from 3 to 20 days	- More than 100,000 Baht up to 500,000 Baht	Power outages between 30 to 100 MW
Low	1	- Minor injuries requiring first aid - Work stoppage not exceeding 3 days	- Up to or equal to 100,000 Baht	Power outage of less than 30 MW

Table 3. Rating for Occurrence (Lygnerud et al. 2022)

Risk Factor	Weight	Criteria	Score	Comment
1. Number of people exposed/ Number of operators	3	>6 people	3	Number of people per job activity
		4-6 people	2	
		1-3 people	1	
2. Frequency/ Exposure duration	3	>30 hrs./week	3	Actual working time for a standard job
		10-30 hrs./week	2	
		<10 hrs./week	1	
Risk Factor	Weight	Criteria	Score	Comment
3. Work procedures/ Safety rules	3	No written procedures	3	-Operating Manual -Work Instruction - Work Practices
		Written procedures available	2	
		Appropriate and written procedures	1	
4. Training	3	No training	3	Training refers to job training and guidance
		Informal training	2	
		Formal training	1	
5. Safety equipment or protection system	3	None/ Inappropriate/ Available but not used	3	Must have records/evidence of work observation
		Appropriate and used	1	
6. Safety inspections/ Maintenance	3	No inspections	3	- General Plan Inspection - PM , Pre-Used
		Inspections without recording	2	
		Inspections with records	1	

7. Health check	2	No health check	3	Health checks according to the nature of the job
		Non-continuous health check	2	
		Regular health checks	1	
8. Job performance observation	2	No observation	3	Must have records/evidence of job performance observation
		Intermittent observation	2	
		Continuous observation	1	
9. Hazard warning	2	None/ Available but not appropriate	3	- Safety signage - Color symbols - Sound/light signals
		Different standards warning	2	
		Appropriate warning	1	
10. Personal Protective Equipment (PPE)	2	None/ Available but not used or inappropriate	3	PPE
		Appropriate and used	1	
Maximum Score (Sum of the highest scores x weight) = 78 (In the case of considering all factors)				

In this research**,** To calculate the likelihood of a hazard (considering all criteria): Take the score obtained from the evaluation (either 1, 2, or 3) and multiply it by its weight (either 2 or 3) for each category. This will give the total score for each category. After that, sum up the scores from all categories to get the aggregate score. Then, compare this with the maximum possible score (the sum of the maximum scores multiplied by the weight for each category equals 78). Calculate this as a percentage using the formula provided below (Table 4-Table 6).

Table 4. Evaluation for Likelihood of Hazard Occurring

$$\frac{\text{Total Sum (Weight x Score) of all considered criteria x 100.}}{78}$$

Table 5. Comparing % with the Likelihood Criteria

Result from Calculation	The likelihood of a Hazard Occurring
>77-100%	High
>55-77%	Moderate
33-55%	Low

By taking the severity (high, medium, low) and the likelihood of the hazard (high, medium, low) and using Table 4, we can estimate the risk level into 5 tiers.

Table 6**.** Risk Rating Table (Holland, 2022)

Hazard Likelihood	Severity		
	Low	Medium	High
Low	Low Risk	Acceptable Risk	Medium Risk
Medium	Acceptable Risk	Medium Risk	High Risk
High	Medium Risk	High Risk	Unacceptable Risk

2.3 Failure Mode and Effect Analysis (FMEA)

The FMEA technique is a hazard identification method that analyzes potential failures to understand the root causes of issues and identifies the effects resulting from such failures. (Bahrami et al. 2012) This analysis looks into the consequences of the damages, leading to a review of existing preventive control measures and any additional measures that might be needed (Table 7 and Table 8).

In assessing risks, this step involves using data from hazard indications, which point to equipment failures and errors in operations, to evaluate the likelihood of their occurrence. For risk assessment, the following criteria should be used:

When considering the likelihood of various events occurring, it is categorized into 4 levels. Moreover, one should consider the severity of these events and how they could impact individuals, communities, assets, or the environment.

Risk ranking is determined by considering the result of the product of the likelihood level and the severity level (Risk = Likelihood x Consequences) that impacts communities, individuals, assets, or the environment. If the risk levels impacting individuals, communities, assets, or the environment differ, one should choose the higher risk value as the result of that particular risk assessment. (Holland, 2022).

Table 7. Risk Ranking Score Table (Risk Matrix 4x4) (Lengyel et al. 2023, Qazi et al. 2021)

Likelihood / Consequence	**Minimal (1)**	**Moderate (2)**	**High (3)**	**Highest (4)**
Minimal (1)	(1)	(2)	(3)	(4)
Moderate (2)	(2)	(4)	(6)	(8)
High (3)	(3)	(6)	(9)	(12)
Highest (4)	(4)	(8)	(12)	(16)

Table 8. Risk Ranking Score Table. (Homan,2019, Roman et al. 2022)

Level	Result	Details
1	1-2	Minimal Risk
2	3-6	Acceptable Risk - Control measures need to be reviewed
3	8-9	High Risk - Actions must be taken to reduce the risk
4	12-16	Unacceptable Risk - Operations must be halted and immediate improvements are needed to reduce the risk.

2.4 Research using the Participatory Approach

Research using the Participatory Approach (Manothum,2009, Cheyrouze,2023, Belgrave,2022) assists in designing work processes to improve occupational safety, health, and environmental conditions. This approach adheres to international organizational standards, such as the OHS (Occupational Health And Safety Management System Series). This standard focuses on minimizing and controlling hazards and risks that lead to injuries, illnesses, and losses to employees and those working on behalf of the organization. The ultimate goal is to elevate safety procedures and achieve the highest standards. The steps involved are as follows:

1. Capacity Building: This involves researching the good and the not-so-good working conditions. Knowledge structures and work processes are organized with safety as a primary consideration. The process involves researchers and stakeholders. At least five experienced maintenance technicians are brought in for a meeting to assess risks in each step of the operation.
2. Risk Analysis: Researchers and at least five experienced maintenance technicians collaborate to assess risks, identify causes, and determine current high-risk tasks. They delve into the root causes and probabilities of these risks. If a risk exceeds acceptable levels, remedial actions must be taken to mitigate it.
3. Problem Prevention & Solving: Once risks have been assessed, efforts should be made to either reduce or control these risks. Safety measures for each high or medium risk task step are identified to create a risk control plan or risk management measures.
4. Monitoring & Communication: This step focuses on revisiting and refining measures that have been implemented and evaluating risks. An action plan is created, and results are monitored to ensure that tasks are performed

correctly and safely, with workers using the appropriate safety gear and adhering to safety rules consistently. Before every task, a 'First meeting' is organized where the supervisor explains the task steps, rules, and safety measures. Workers then sign to acknowledge they understand the risk mitigation measures

3. Method

The Operational Research System for Reducing Risks in the Control and Maintenance of High Voltage Transmission Lines can be divided into 5 steps as follows (Figure 3):

1. Compilation of Work Inventory: Gathering a list of tasks related to the maintenance of High voltage transmission lines.
2. Impact Consideration: Evaluating the impacts on people, equipment/machinery, and the environment during operations.
3. Risk Assessment Process: A systematic procedure to understand the nature of and the risk from potential hazards.
4. Risk Control Measures: Implementing strategies and techniques specifically designed to control, reduce, or eliminate potential risks.
5. Linking Risk Assessment with Control Measures: Integrating the findings from the risk assessment process with appropriate control measures to ensure a comprehensive approach to hazard management

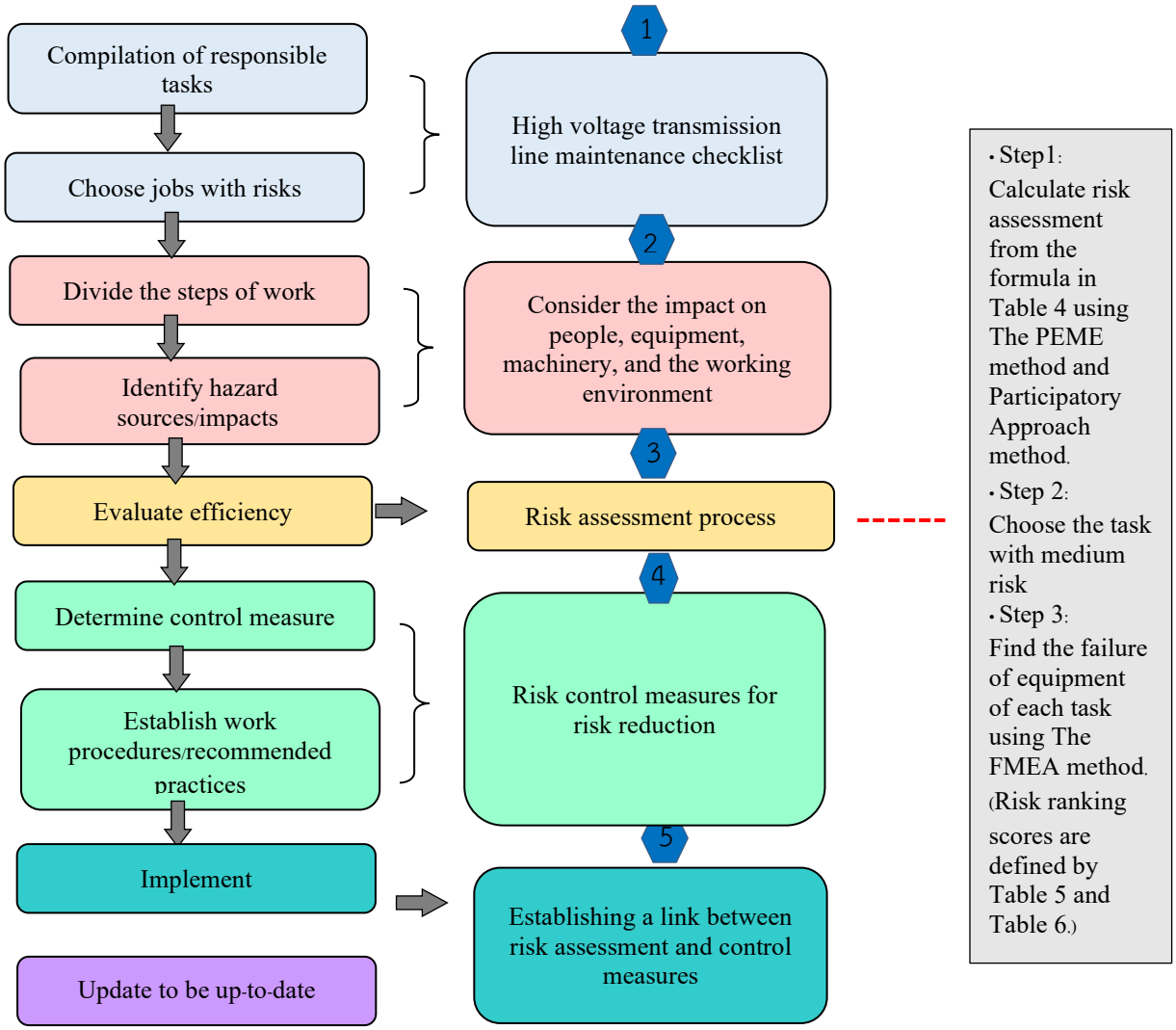

Figure 3. Illustrate the research process steps (Huang,2023)

4. Results and Discussion

4.1 Risk Assessment Results

We selected 31 maintenance jobs from the maintenance job list and conducted a risk assessment according to the Quality Management System, Occupational Health and Safety Management, and Environmental Management principles. We analyzed safety aspects according to the PEME principles and ranked the risks. After that we received tasks with medium to high-level risks for analyzing FMEA principles. The research results provide information on risk management measures and practices for high-risk jobs identified from the risk assessment. This can help reduce personal, property, and production process losses related to electrical current incidents that occur within the organization.

1. High severity, Low hazard likelihood = Moderate-risk level: 19 jobs :
   - 1.1 Inspection of transmission lines with a helicopter
   - 1.2 Annual inspection of 115,230, and 500 kV transmission lines (Climbing)
   - 1.3 Checking Puncture Insulator on Transmission Tower
   - 1.4 Checking ESDD
   - 1.5 Replace Insulator 115, 230, and 500 kV work while high voltage power is turned on (Hot Line)
   - 1.6 Replace Insulator 115, 230, and 500 kV work while high voltage power is turned on (Dead Line)
   - 1.7 Repair any broken OPGW/OPGW wires
   - 1.8 Repair any broken Conductor wires
   - 1.9 Fix the spacer damper, Aerial Sign Ball loose, sliding
   - 1.10 Insert the steel bolt & nut in place of the original one that was stolen
   - 1.11 Repair the smart camera
   - 1.12 Washing the insulator on the steel tower while high voltage power turns off
   - 1.13 Repair any faulty bird-dropping prevention equipment
   - 1.14 Unplug the Jumper loop Conductor cable
   - 1.15 Work on transmission line upgrades
   - 1.16 Setting Transmission line surge arrester: TLA
   - 1.17 Setting a smart camera on the steel tower
   - 1.18 Transmission line construction work inspection
   - 1.19 Setting Aerial sign ball
2. Moderate severity, Low hazard likelihood = Acceptable-risk level: 2 jobs
3. Low severity, Low hazard likelihood = Low-risk level: 10 jobs

After analyzing all risks get work with high, medium, and low risks to create measures to control the risks that will occur. To avoid the danger that causes injury or death. After risk assessment, These allow us to know if any jobs are carefully worked out. And whether or not the operators are working with the possibility of risks occurring.

4.2 Collecting Risk Control Measures for Risk Reduction

All risk control measures for reducing the risks associated with the operation, control, and maintenance of high-voltage power transmission lines are gathered to establish preventive measures or control methods to prevent or maintain risks at an acceptable level within the organization. The following guidelines are proposed:

1. Health and safety management system.
2. Use of personal protective equipment (PPE)
3. Rules and work permits
4. Equipment inspection before use
5. Development of work procedures and practices
6. On-the-job training
7. Work observation system.

5. Conclusion

Analyzing and Developing Risk Reduction Measures for High-Voltage Power Transmission Line Maintenance Work is applied for practical work in safety for high-voltage power transmission line maintenance. This can be summarized as follows:

5.1 Job Analysis According to Work Categories

The analysis of high-voltage power transmission line maintenance work categorizes it into various types, such as preventive maintenance, corrective maintenance, and adaptive maintenance. Each activity within the work is examined to understand who might be at risk and how. This analysis helps identify measures to mitigate risks and maintain them within acceptable levels, aligning with the organization's standards.

5.2 Risk Assessment Process

The risk assessment process follows quality management, occupational health and safety, and environmental management systems. It involves conducting Job Safety Analysis (JSA) based on the PEME principles. For work activities with moderate or higher risks, Failure Mode and Effect Analysis (FMEA) is conducted to determine preventive measures or control methods. These measures are designed to prevent or manage risks within acceptable levels, reducing the likelihood of accidents or hazards.

5.3 Consideration of Risk Control Measures

The results of the job analysis, which assessed the impact on people, equipment, machinery, production processes, and the work environment, provided guided the establishment of risk control measures for high-voltage power transmission line maintenance work. These measures include seven categories:

1. Health Care Plan for Workers: Regular health checkups and assessments of workers' fitness for duty.
2. Use of Personal Protective Equipment (PPE): Adequate and suitable PPE, such as head protection, face and eye protection, hand protection, and fall protection equipment, is provided.
3. Work Rules and Permits: Specific work rules and work permits are established for 15 types of work activities.
4. Equipment Inspection: Procedures for inspecting equipment and machinery before use.
5. Work Procedures and Practices: Written procedures or practices are developed for 19 moderate-risk jobs.
6. On-the-Job Training: Training is provided before commencing work.
7. Work Observation Systems: Systems for observing work, including comprehensive work observations and spot checks.

5.4 Establishing the Link between Risk Assessment and Risk Control Measures

Considering the impact on people, equipment, machinery, production processes, and the work environment for risk assessment helps determine the level of risk, severity, and likelihood of danger for each job. The assessed risk levels are divided into three categories: moderate risk, acceptable risk, and low risk. Risk control measures are established in two categories: static and dynamic. Static measures are used for constant risks and are depicted as green circles. These measures include:

- Health checkups
- Personal protective equipment (PPE)
- Work rules and permits
- Work procedures and practices
- Equipment inspection before use

Dynamic measures vary based on the assessed risk levels for each job. When the risk assessment indicates a risk level lower than moderate risk, the control measures may change depending on the job's importance. These measures are depicted as blue circles and include:

- Internal on-the-job training
- Work observations

6. Recommendations

1. Being Open and Prepared to Face Risks in Every Work Operation

It is not always possible to eliminate risks from certain types of work due to various factors such as cost considerations and regulations. Therefore, when risks are within acceptable levels, it is important to be open and prepared to face those risks.

2. Organizations should encourage employee involvement and an open mindset in the analysis and development of risk control measures for high-voltage power transmission line maintenance work. Management should provide support to ensure that employees actively participate in work analysis and engage in open discussions to gather the most accurate information.

3. Work analysis should involve experienced individuals from various levels of management, department heads, and operational staff. Their participation in the analysis process will help the organization manage risks more effectively.
4. To ensure that risk management aligns with risk control measures, management should push for practical implementation. Incentives and mechanisms for change and practical application should be in place.

- Management issues a policy requiring employees to adhere to risk control measures and announces it widely.
- Employees who violate or fail to comply with risk control measures, and whose actions result in damage to the organization's property due to deliberate misconduct, are required to compensate for the damage based on the criteria established by the organization.
- If employees' compliance with risk control measures leads to the absence of losses within the organization, management should consider this as a contributing factor in evaluating their performance, rewards, or commendations.

5. Guidelines for Transmitting Risk Control Measures to Operational Level Workers should be implemented as follows:

- Conduct training for maintenance and operation personnel to make them aware of job-specific rules and regulations as per the risk control measures.
- Develop step-by-step work procedures and instructions with moderate risk for all personnel.
- Before starting any task with moderate risk, the supervisor should conduct on-the-job training each time to review the work procedures, and all personnel must sign that they understand these procedures.
- Implement an observation system to assist in performing tasks with the involvement of experienced observers appointed by management to identify improvement areas and find ways to enhance strengths.

References

Alexander, J. Oliveira, G. Garcia, M. Mendonça, N. Silva, C. Garcia, P. And Badibanga, R. A case study of glass insulator pin failure in 500 kV transmission line, 2023

Arocena, P. Orcos, R. And Zouaghi, F. The scope of implementation of ISO 14001 by multinational enterprises: The role of liabilities of origin, 2023

Bahrami, M. Hadizadeh, D. Bazzaz, S. And Sajjadi, M. , Innovation and Improvements In Project

Belgrave, A. Bermudez, N. Chew, P. Lin, Y. Ahn, J. And. Bustamante A., Using a participatory design approach for co-creating culturally situated STEM enrichment activities, 2022

Cheyrouze, M. And Barthe, B. Designing shift work: Proposal for a participatory approach deployed in a hospital setting and focusing on actual work, 2023

Fekri, M. Nikoukar, J. Gevork B. Gharehpetian, Vulnerability risk assessment of electrical energy transmission systems with the approach of identifying the initial events of cascading failures, 2023

Ghasemi, F. Doosti-Irani A. And Aghaei H., Applications, Shortcomings, and New Advances of Job Safety Analysis (JSA): Findings from a Systematic Review, pp.153-154, 2023

Holland, C. Obstertics Gynaecology and productive medicine, 2022

Homan, Department of Defense Standard Practice) , System safety : Risk Assessment Matrix , April 2019

Huang, X. Yuanqiao, W. Zhang, F. Han, H. Huang, Y. And Sui, Z., A review on risk assessment methods for maritime transport, pp.2 , 2023

Implementation and Management; Using FMEA Technique, 2012

Lengyel, D. Mazzuchi T. And Vesley W., Establish Risk Matrix standard criteria for

Lygnerud, K. Klugman S. Fransson N. Nilsson J, Risk assessment of industrial excess heat collaborations e Empirical data from new and ongoing installations, 2022

Manothum, A. The development of occupational health and safety management model for the informal-sector workers using a participatory approach, Chulalongkorn University , 2009

Qazi, A. Shamayleh, A. El-Sayegh, S. And Formaneck S., Proritizing risks in sustainable construction projects using a risk matrix-based Monte Carlo Simulation Approach, pp.5-6 , 2021

Rachel. Occupation Safety Group, Recognizing, Assessing, Controlloing & Evaluating Hazards, 1 March 2017, Available at https://osg.ca/recognizing-assessing-and-controlling-hazards/

Rajkumar, I. Subash, K. Raj Pradeesh, T. Manikandan, R. And Ramaganesh, M. Job safety hazard identification and risk analysis in the foundry division of a gear manufacturing industry, 2021

Reniers, G., Safety Management Systems: History, Approach, Design, Elaboration, and Implementation, 2014, pp.1-8

Roman, L. Denise, B. And Schuyler Q., A systematic and risk matrix of plastic litter impacts on aquatic wildlife: A case study of the Mekong and Ganges River Basins, pp.7-8 , 2022 use in the continuous risk management process, Journal of space safety engineering , pp.3-6 , 8 May 2023

Biographies

Nuttanicha Panich is currently a Master of Engineering student in Industrial Engineering at Chulalongkorn University**.** She studied Civil Engineering at Thammasat University Bangkok, Thailand**.** She has over 6 years experience in civil engineer in the field of transmission line maintenance**.** Her research is on Reducing Risks in the Maintenance of High-Voltage Transmission Lines.

Jittra Rukijkanpanich is an Associate Professor in the Department of Industrial Engineering at Chulalongkorn University, Bangkok, Thailand. She studied Bachelor's degree in agricultural at Kasetsat University, Her Master degree is Industrial Engineering from Chulalongkorn University and Doctor of Philosophy degree in industrial systems engineering at Asian Institute of Technology in 1998, 1990 and 1997 respectively. Her research is mainly about maintenance engineering and management, decision support system and safety engineering.