Risk Assessment of Accidents in Chaharmahal and Bakhtiari Power Distribution Company using Tribod-Bets and AHP Method

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Abstract

Analyzing accidents in order to identify their causes is one of the most important stages of accidents. With the help of descriptive-analytical analysis, this research deals with the evaluation, analysis and analysis of recurring incidents in the electricity distribution company of Chaharmahal and Bakhtiari province using Tribod-Beta and AHP methods. Considering the most important factor of human error, the Tribod-Beta method is one of the best methods in the analysis of incidents in electricity distribution companies. It has been drawn, to know the causes and problems related to the change, we will review the correction to prevent the occurrence of similar incidents. Considering the importance of the issue and confirming the non-interference of personal taste in the analysis of accidents, we weight the results using the AHP method. According to the obtained results, it can be said that non-observance of safety principles with 50% frequency and with the highest standard weight (0.5 and 0.1958) is one of the most risky causes of accidents in four frequent accidents.

Keywords: Incident analysis , Rooting of incidents , Tribod-Beta and AHP methods

1.Introduction

Today, the electricity industry is one of the vital infrastructures of other industries and plays an important role in the industrial and economic development of developing countries due to the gross domestic product. Every year, various incidents occur with the expansion and development of this industry, which cause serious damage to human resources, which are the most important and influential pillar in advancing the goals of the electricity industry. [1,2] According to the Occupational Safety and Health Administration (OSHA) report, 86% of casualties are in the electricity generation, transmission and distribution sector, which leads to the loss of 12,976 working days per year. Also, OSHA and NIOSH institutes, by examining 244 major accidents, have reached the following five scenarios that led to the accident:

28% of direct contact of employees with power lines, 21% of direct contact of employees with electric network equipment, 18% of contact with the electric network, 17% of worn out or damaged equipment of the electric network and 16% of conductive equipment contact with electric lines [3,4].

The word "accident" is defined as an unforeseen event that interrupts the performance of an activity and may be associated with injury or financial damage. The basis of incident control is the creation of appropriate control and defense systems in such a way as to prevent the intersection and interaction of the risk factor and the target factor. Investigating the root causes can help a lot to solve safety problems in the organization and have a significant effect on reducing accidents. Among these reasons, we can point out errors in the design, defects in the policy and poor training. The use of incident analysis techniques in a radical and structured way such as tripod beta technique

in the organization can provide important results such as reducing costs, reducing damages and most importantly, working in a safe environment, all of which These results will lead to increased productivity. In addition, the use of these techniques in the topic of modern risk management can be very useful in identifying risk in a reactive manner. Considering the importance of personal non-interference in risk assessment decision-making, AHP method can be used.

In the health and safety system, the most important part is the identification and assessment of risk caused by danger (accident). Risk assessment is the process of identifying, analyzing and evaluating potential risks related to a specific activity or situation. This process consists of three main parts: risk identification, risk estimation and risk assessment [5,6,7,8]. For risk assessment, he pointed out different methods, including: job safety analysis (JSA), process hazard analysis (HAZOP), broken state analysis and its effects (FMEA). With the increase and complexity of incidents, risk assessment techniques are progressing and updating [9,10]. In this regard, due to the number of accidents in electricity distribution companies, we must look for methods for risk assessment that are flexible and correctly address the role of human factors as one of the causes of accidents.Studies have been conducted in the world on the risk assessment of accidents that occurred in electricity distribution companies, which can be cited as follows:

In 2023, Mohsen Sadeghi Yazdi and his colleagues have conducted a study on the safety risk index in the electricity distribution industry. This process was carried out using the fuzzy hierarchical method (FAHP) on three individual, environmental and organizational components with the participation of 30 experts. In this study, the personal component (PC) with a weighted average of 0.537 and the Cronbach's Alpha coefficient for each of the individual, environmental and organizational components were calculated as 0.90, 0.85 and 0.82%. [11]

In 2021, a study was conducted on the analysis of incidents that occurred in Tehran Electricity Distribution Company, and the data from 2010 to 2017 was collected from the database of the safety department. The results show that 75% of the accidents occurred in the summer due to the heat of the air and insufficient skills of the employees [12].

In 2022, Moin Kayani and his colleagues investigated the safety climate and its structural dimensions in an electricity distribution company. The questionnaire contains 43 questions in 11 dimensions, which have been analyzed using spss software. The results show that among the safety climate factors, the highest score was related to safety training (87.3 percent) and the lowest score was related to work pressure (80.2 percent) [13].

In 2019, Adel Mazloumi and colleagues have conducted a study on the evaluation of human errors in the operation of electrical installations of the Greater Tehran Power Distribution Company. Using the analysis of SHERPA worksheets, researchers have analyzed 3399 errors, of which 39.57% were functional errors, 32.04% were review errors, 7.32% were retrieval errors, 19.67% were communication errors, and 1.80% were selection errors. [14]

In 2021, a study was conducted on the identification of hazards and risk assessment in the electricity distribution company of Yazd province. Researchers evaluated 198 risks using HAZIDSTUDY and FMEA methods, and the result of this research was that 5.05% of risks were in the intolerable range, 24.95% of the risks were in the moderate range, and 70% of the risks were in the tolerable range [15].

2. Analysis method

This research is descriptive-analytical. In this research, we analyze four frequent incidents that occurred from 2012 to 2023 in the electricity distribution company of Chaharmahal and Bakhtari province. In this research, we use the Tribod Beta and AHP method due to considering the direct causes, indirect causes, obvious causes and hidden causes of the accident. In the Tribod-Beta method, we use the investigator software to draw the event tree and use the AHP method to weight the criteria and sub-criteria.

2.1. Tribot - Beta evaluation method

Today, the use of hazard identification and risk assessment methods is expanding in various industries, so that currently there are more than 70 different qualitative and quantitative risk assessment methods and techniques in the world. These methods and techniques are usually used to identify, control and Reducing the consequences of risks is used. Most of the existing methods of risk assessment are suitable methods for assessing risks and their results can be used for management and decision making regarding the control and reduction of its consequences without worry, each industry can use this method depending on its needs. have different advantages and disadvantages compared to each other. Therefore, one of the duties of the existing health and safety management system in every industry (HSE) is to check all the methods of assessing risks and dangers and choosing the appropriate method for implementation in the respective industry and organization. In general, it can be said that from the type of method used in risk assessment and the depth of its assessment, the ability of the existing safety system can be understood to some extent, and as a result, the safety management method in the mentioned industry [6,7] Therefore, due to the high sensitivity of safety in the electricity industry and considering the unfortunate consequences, the need for continuous monitoring of reinforcement, evaluation and elimination of hazards in the field is felt. Therefore, after studying and reviewing the existing methods and techniques, the Tripod-Beta method in terms of cost, execution time, simplicity, ease of showing the relationship between human errors, training, implementation and implementation without the need for software, graphical description of the event and analysis Incidents have been selected from two aspects of control and defense in the electricity industry. The theory of this method is based on the Swiss cheese model, and due to its methodology and standard tables, it is widely used and cited in various organizations and industries. It provides relatively comprehensively. By using this method, it is possible to identify the superficial causes, preconditions, and hidden causes that caused the occurrence of unsafe behavior and conditions, determine the path of the accident, and identify the defects in the control and defense systems that are caused by failure to act. He stated that they caused the accident in time [16,17,18]. The basis of this analysis is based on three pillars, Hazard, Target, and Event. Tribod - Beta tree is as follows:

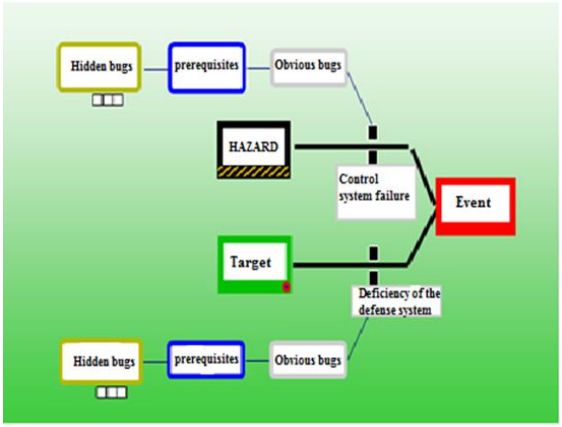

Fig.1. Tree of this incident by Tribod- Beta method

The method of analyzing incidents based on the Tripod Beta model

1. Draw the tree and determine the risk, goal and event
2. Specifying protection systems (control and defense)
3. Determining surface defects (unsafe practices or unsafe conditions)
4. Using checklists to determine preconditions and hidden problems 5. Determining the list of preconditions and hidden problems effective in the occurrence of an accident based on the checklist and entering them in the relevant table to manage hidden problems.

- Tribod-Beta chart symbols:

- **EVENT**

An event is a change of state that results from the interaction of a hazard on a target. Important events in electricity distribution companies can be mentioned as: transformer explosion, medium pressure electrocution, falling from the power base. [19].

- **HAZARD**

It's either a source of energy, matter, or the potential to be harmed, or damag. Like heat, electricity, flammable chemicals, height [20]

- **TARGET**

It is the subject or case that the risk has affected and probably caused damage to it, and it includes four groups as follows:

A- People (injury or damage to the health ofpersonnel or third parties)

B- Equipment/capital (damage to unit or equipment, loss of materials, interruption or stoppage of operations, damage to third party capital)

C- Environment (damage and pollution in the environment)

D- Validity(mass media controversy, public attention, protest, prosecution, commercial restrictions, regulations) [21]

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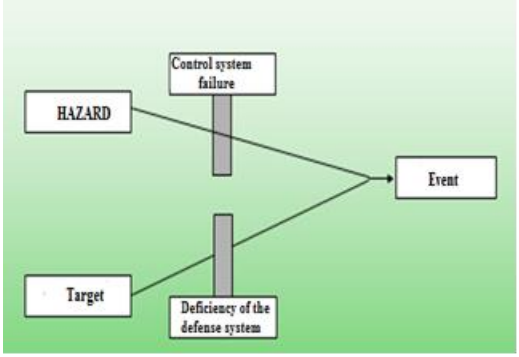

Fig.2. Events management diagram

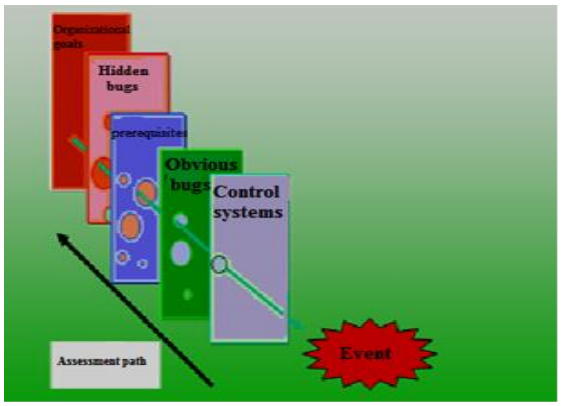

Fig.3. Path of finding the cause by the Tripod -Beta method

2.2. ANALYTICAL HIERARCHY PROCESS (AHP)

Hierarchical analysis process is one of the decision making methods. AHP stands for Analytical Hierarchy Process. This method is one of the most widely used methods for ranking and determining the importance of factors, which is used to prioritize each of the criteria with paired comparisons of options, which is called weighting the criteria [22,23].

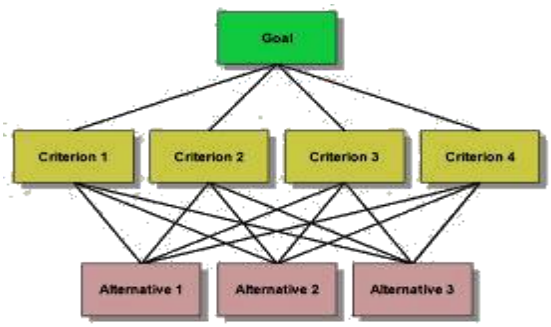

Fig.4. Hierarchical Process (AHP)

The first step of the AHP process is the selection of criteria and in the next steps , alternatives are evaluated based on the identified criteria. In this method, all factors and criteria are compared two by two and placed in the weighting matrix. The comparison scale is placed in the range of 1 to 9, as described in the following table [24]:

Table 1. comparison numbers of factors two by two

Description	Severity Of importance
Maximum superiority value	9
Superiority value is maximum to high	8
The value of excellence is very high	7
High to very high superiority value	6
High superiority value	5
Moderate to high superiority value	4
Average excellence value	3
Same to medium excellence value	2
Equal excellence value	1

To perform the hierarchical analytical process, we act as follows:

First step: We create a hierarchical structure with a goal at the top level, criteria at the second level and options at the third level.

second step: according to the relative importance of each criterion, a pairwise comparison matrix is formed and finally, the normal matrix is calculated.

Third step: In this step, according to the values of the normal matrix and the number of criteria, we calculate the weight of the criteria as follows

$$Criteria\ Weight = \frac{Iements\ In\ each\ row\ of\ the\ sum\ normal\ matrix}{RINumber\ of\ criteria} \quad (1)$$

Fourth step: Using the pairwise comparison matrix and the criteria weight of each element, we calculate the compatibility rate. Then, by summing all elements of compatibility rate, we get the weighted sum.

Fifth step: In this step, according to the weighted sum values and the weight of the criteria, we will calculate the compatibility vector as follows.

$$\text{Compatibility vector} = \frac{Weighted\ total\ values}{criteria\ weighted} \quad (2)$$

Sixth step: In this step, we calculate the largest eigenvalue of the matrix of pairwise comparisons (λmax) by dividing the sum of the compatibility vector by the number of criteria.

$$\lambda max = \frac{Compatibility\ Vector\ Sum}{Number\ of\ criteria} \quad (3)$$

Seventh step: In this step, we calculate the incompatibility index as follows:

$$CI = \frac{\lambda max - n}{n-1} \quad (4)$$

Eighth step: By dividing the value of the inconsistency index by the random index, we calculate the inconsistency ration[11].

$$CR = \frac{CI}{RI} \quad (5)$$

Random index or RI is a fixed value and its value depends on the number of criteria. The table of its values is as follows:

Table 2. Randomness index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Note that the value of the inconsistency rate must be greater than 0.1, in this case the determined criteria are logically compatible.[24,25]

The flowchart of the Analytical Hierarchy Process (AHP) is as follows:

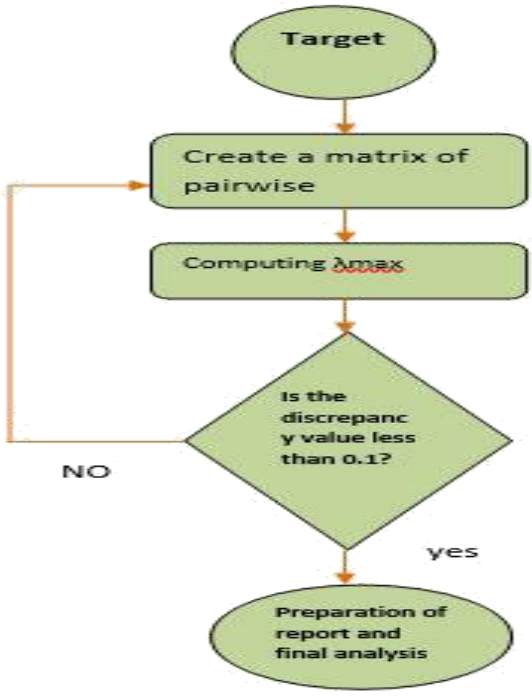

Fig.5. AHP process flowchart

3. Results

According to the table below, we evaluate the risk of four incidents that occurred in the power distribution company of Chaharmahal and Bakhtiari province using the Tribod-Beta and AHP methods.

Table3. Frequent events

Sickness period / death	Corrective actions	Consequences	cause of the accident
sick days 20	Enclosing the work environment - using a helmet	Breaking the person's head and neck	Falling objects on a person
death of the person	Covering the power grid - complying with the legal distance between the lifting boom and the power grid	Passing electric current through a person's hand and heart	Low pressure electrocution
death of the person	Harnessing the electric pole with a crane-repairing the pit of the electric pole base	The base falls on the person	Falling with a concrete base
45 sick days	Disconnecting the public electricity distribution and measurement board - using medium pressure gloves (class 01)	Creating a severe arch and burning the face	Entering the area of the electrical panel

- Description of the incident on 2019/10/08

After going to work, the person was injured in the head and neck area. While carrying out the modification and optimization of the electricity distribution network, without safety equipment, the mentioned person entered the area of the operation of Simban forces and by releasing the aluminum wire from the insulator, he caused injury to the head and neck of the mentioned person. The Tribod-Beta diagram of this incident is as follows.

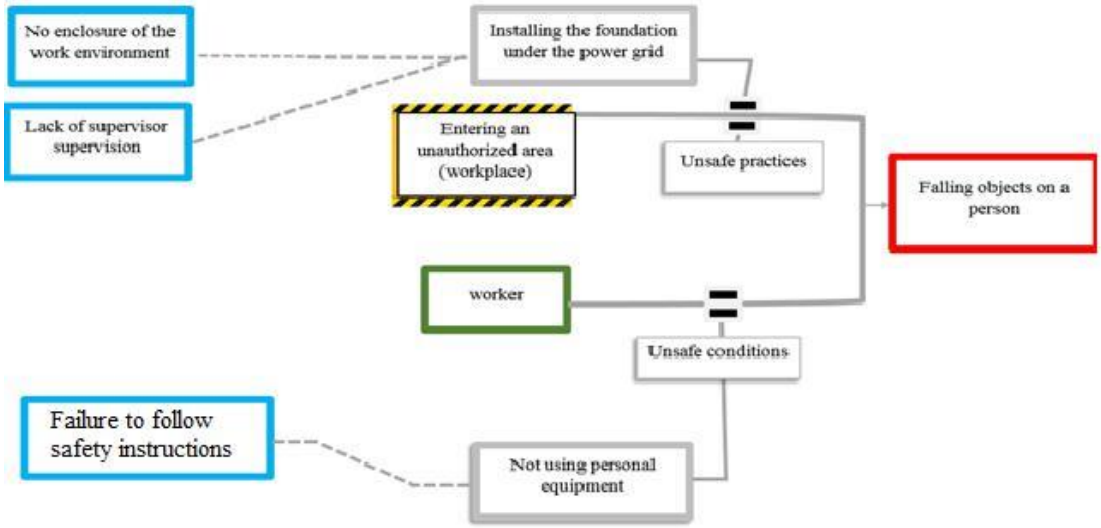

Fig.6. Tripod-beta accident diagram2019/10/08

- Description of the incident on 2021/12/05:

The mentioned person was sent to the workplace with a lift truck to repair the network and replace the lamp. Unfortunately, while working on the network, the mentioned person did not observe the legal distance between the boom and the power grid, and also his colleague, who was responsible for guiding the boom on the ground, negligently did not notice what happened and caused a severe electric shock. It led to the death of the mentioned person. The tribod-beta diagram is as above.

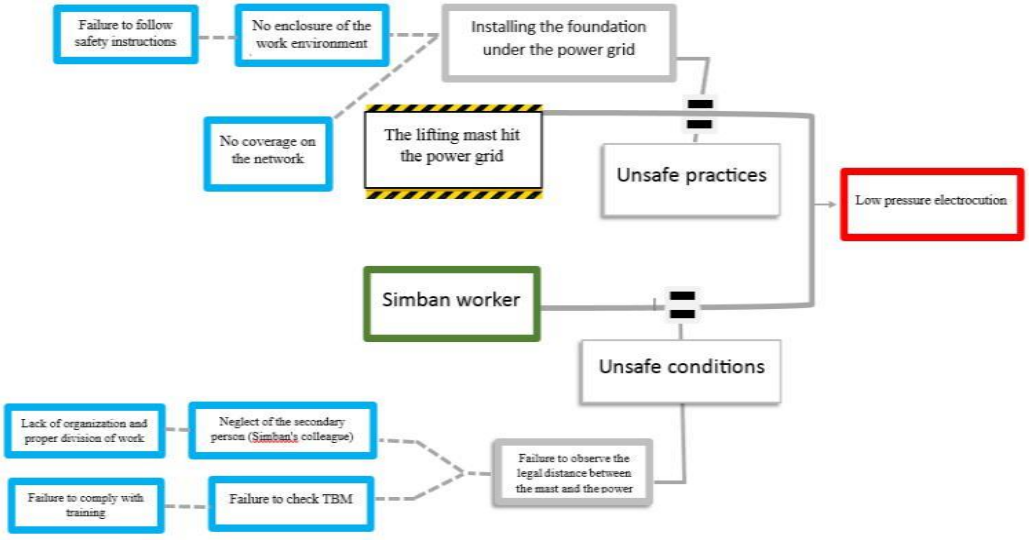

Fig.7. Tripod- beta accident diagram2021/12/05

The Simban force was sent to the work place along with their colleagues to move the electricity distribution network. The mentioned person has climbed the pole without considering the principles of work safety to remove the power grid. Due to the excavation of the place where the pole was installed by the highway department, the pole in question lost its strength and when the mentioned person climbed, the pole came out of the hole and caused the person to fall and die.

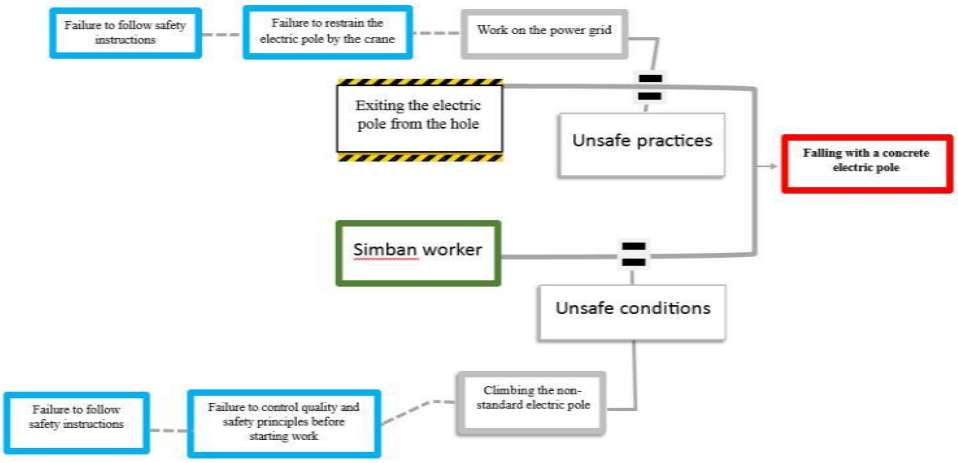

Fig.8. Tripod- beta accident 2022/07/12

- Description of the incident 2023/02/19:

The lighting force is sent to the place to improve the lighting network of the city. Without paying attention to the principles of safety and not using personal safety equipment, the said person cut off the fuse switch inside the lighting panel, and while his hand hit the electric ingots of the panel, he encountered a severe arc of the panel, which unfortunately caused electrocution and burns to his hand. And he was sent to the hospital with the coordination of the emergency center.

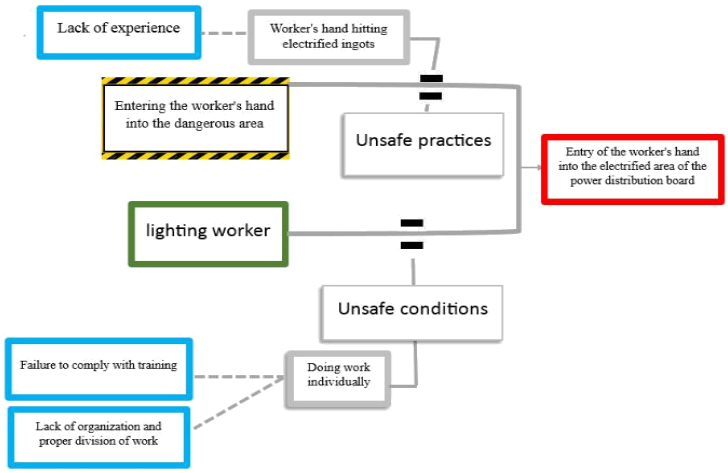

Fig.9 Tripod- beta accident 2023/02/19

According to the trees of the above accidents, non-observance of safety instructions with a frequency of 50% is the most common cause of accidents in the category of unsafe conditions, and in the category of unsafe practices, all three options have caused accidents with the same frequency.

Table 4. The frequency of incidents

The root causes of accidents in unsafe conditions	grace Frequency	The root causes of accidents in unsafe practices	Grace Frequency
Failure to follow safety instructions	%50	Failure to comply with training	%66.6
No enclosure of the work environment	%25	Lack of organization and proper division of work	%66.6
Lack of supervisor supervision	%25	Non-observance of personal safety principles	%66.6
Lack of experience	%25	-	-

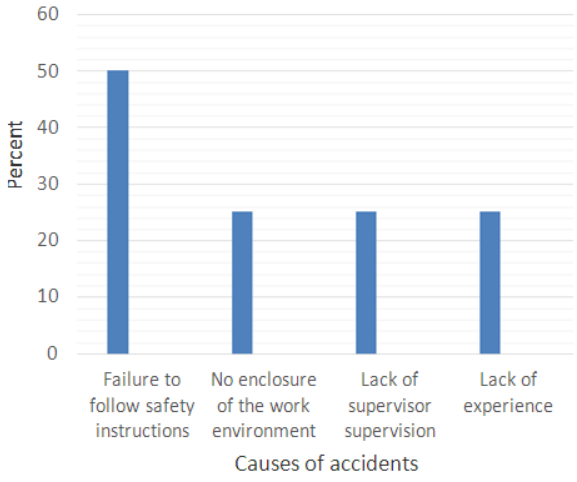

Fig.10. Diagram of causes of accidents in unsafe conditions

Fig.11. Diagram of causes of accidents in unsafe practices

Considering the importance of the subject and the absence of personal tastes in the analysis of accidents, we use the AHP method to analyze the causes of accidents and by giving weight to each of the defined criteria, we choose the main cause. To analyze an AHP method, we do the following:

In the first step, by defining a high-level goal, we specify criteria and sub-criteria to form a hierarchical structure. Hierarchical structure with the aim of analyzing the cause of the accident in the electricity distribution company of Chaharmahal and Bakhtiari province is as follows:

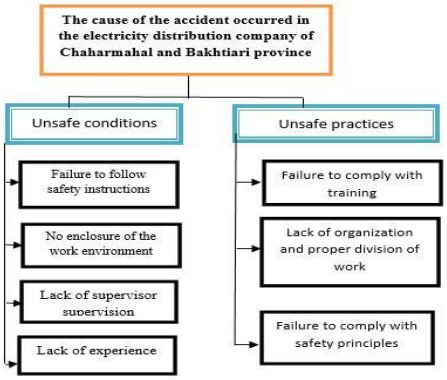

Fig.12. Hierarchical structure

In the second step, we form a pairwise comparison matrix for the criteria and sub-criteria of unsafe actions:

Table 5. Pairwise comparison matrix in unsafe practices

Failure to comply with training	Lack of Organization and proper division of work	Failure to comply with safety principles	
1.8	2.25	1	Failure to comply with safety principles
0.8	1	0.44	Lack of organization and proper division of work
1	1.25	0.55	Failure to comply with training

In the third step, we will calculate the criterion weight and compatibility rate as follows:

Table 6. Criterion weight matrix and compatibility vector in unsafe practices

Compatibility vector	Weighted Criteria	
2.96	0.5	Failure to comply with safety principles
3.11	0.22	Lack of organization and proper division of work
3.037	0.27	Failure to comply with training

$$\lambda max = \frac{2.96+3.11+3.037}{3} = 3.03$$

$$CI = \frac{3.036-3}{2} = 0.018$$

$$CR = \frac{0.018}{0.58} = 0.031$$

According to the criterion weight obtained, it can be said that non-compliance with safety principles with a criterion weight of 0.5 is the first priority, non-compliance with training with a criterion weight of 0.27 is the second priority, lack of organization and proper division of work with a criterion weight of 0.22 is the last priority. have dedicated themselves. Also, according to the obtained compatibility rate (CR=0.03<0.1), it can be said that the selected criteria are logically compatible. The fourth step: We form a pairwise comparison matrix for the criteria and sub-criteria of unsafe conditions as follows:

Table 7. Pairwise comparison matrix in unsafe conditions

Lack of experience	Failure to follow safety instructions	Lack of supervisor supervision	No enclosure of the work environment	
0.5000	0.6861	0.6002	0.6289	No enclosure of the work environment
0.2143	0.0858	0.1200	0.1251	Lack of supervisor supervision
0.2143	0.1715	0.2401	0.1572	Failure to follow safety instructions
0.0714	0.0572	0.0400	0.0898	Lack of experience

In the fifth step, we will calculate the criterion weight and compatibility rate as follows:

Table 8. Criterion weight matrix and compatibility vector in unsafe conditions

Weighted Criteria	Compatibility vector	
0.603	4.1762	No enclosure of the work environment
0.1365	4.0225	Lack of supervisor supervision
0.1958	4.1553	Failure to follow safety instructions
0.0646	4.0488	Lack of experience

$$\lambda max = \frac{4.176+4.0225+4.1553+4.0488}{4} = 4.1007$$

$$CI = \frac{4.1007-4}{2} = 0.03355$$

$$CR = \frac{0.03355}{0.90} = 0.0372$$

According to the above calculations, failure to comply with safety instructions with a criterion weight of 0.1958 in the first priority, lack of supervisor supervision with a criterion weight of 0.1365 in the second priority, lack of enclosure of the work environment with a criterion weight of 0.603 in the third priority and lack of sufficient experience with a criterion weight of 0.0464 in the last priority has assigned Also, according to the obtained compatibility rate (CR=0.0372<0.1), it can be said that the selected criteria are logically compatible.

Offers in order to prevent the repetition of the mentioned incidents, we suggest corrective measures for each of the incidents as follows:

A. Corrective measures for the incident dated 2019/10/08

- Enclosing the work environment
- Passing and browsing in the safe area
- Checking personal safety equipment
- Employing a health and safety expert during work
- Using a lift to replace electric wires

B. Corrective measures for the incident dated 2021/12/05

- Covering the low voltage power grid
- Doing work in groups
- Employing a lift operator
- Using personal equipment, especially class 01 gloves
- Shutting down the low pressure network for repairs
- Use of earth in weak pressure network

C. Corrective measures for the incident dated 2022/07/12

- Filling the TBM form before work
- Testing the strength of the electric pole before climbing
- Controlling the electric pole by the crane while climbing

-Using a lifting device to remove the electricity distribution network

D. Corrective measures for the incident dated 2023/02/19

- Separate the lighting board from the power distribution board
- Use of safety equipment (face shield - class 01 gloves)
- Doing work in groups
- Using the automatic switch in the lighting panel
- Using covered ingots

- Disconnecting the feeders with the cardi fuse key
- Fulfilling the requirements of the TBM form

4. Conclusion

In this research, the risk assessment of four frequent accidents in the electricity distribution company of Chaharmahal and Bakhtiari province was done using the Tribod Beta-AHP method. The obtained frequency percentage can be said that non-observance of safety principles with 50% frequency is the highest risk. Also, by giving weight to each of these causes, we came to the conclusion that non-compliance with safety principles has the highest criterion weight. In the end, by using the suggested solutions, we have prevented the recurrence of these incidents.

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