ELECTRICAL SAFETY ASSESSMENT OF POWER INDUSTRY

Nitesh Pal[1], Sanjay Kumar Sahu[2], Sandeep Saha[2]

[1]*M.Tech. Scholar, Bhilai Institute of Technology, Raipur, Chhattisgarh*
[2]*Assistant Professor, Bhilai Institute of Technology, Raipur, Chhattisgarh*

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Abstract - *As one of the most hazardous source at a construction sites and a symbol of modern construction operations, electricity possesses the capacity of powering all the tools and machineries at any construction site. In this research, the author aims to understand the different underlying electrical safety hazards in power industry and to understand the different methods to identify the underlying hazards. Also the author aims to learn the appropriate remedial measure or recommendations for the identified hazards. The methodology adopted in the research work also uses*
The objective of this study is to examine the different underlying electrical safety hazards in power industry and to understand the different methods to identify the underlying hazards. A secondary objective is to evaluate the effectiveness of the AHP (Analytical Hierarchical Process) method to prioritize the identified flaws in the system so that the important electrical flaws can be addressed first on the basis of a pre-determined priority. Lastly, this research was undertaken to help develop specific best practices concerning electrical operations

Key Words: Electrical Safety, HIRA, AHP, Power Industry

1.INTRODUCTION

The utilization of electricity has become an integral and essential component of contemporary life, and as such, it presents numerous safety risks that pose a threat to the well-being of people and property. These hazards take the form of electrical shock, burns, injury, fire, and explosions. Despite electricity's automatic nature and its absence of smell, visibility, or sound, its dangers are real and ever-present. In the past, hotels were forced to assure guests that electricity was innocuous, but today, warnings about its dangers are commonplace. The shift from viewing electricity as a silent ally to a perilous hazard has been challenging for many to comprehend until it is too late. Consequently, the implementation of robust electrical safe work practices is necessary to safeguard the welfare of workers. This includes guidelines for personnel qualification, job planning requirements, and management, among other aspects.

Comprehending the measures and protocols utilized in a well-designed electrical safety program necessitates an appreciation of the inherent dangers posed by electricity. Although a compact definition of these perils may elude most individuals, the sensation of electric shock is a familiar experience that leaves an enduring impression on the human psyche. Nonetheless, electric shock is but one of several electrical hazards, including arc, blast, acoustic, light, and toxic gases. This chapter delineates each of these hazards and elucidates their impact on the human body. However, comprehending the nature of these hazards is unproductive unless protective strategies are devised to safeguard workers from potential harm.

Annually, electricity utilization at construction sites results in numerous accidents that can result in electric shocks and burns, potentially leading to severe and even lethal injuries. Furthermore, such accidents can also cause individuals to fall from ladders, scaffolds, and other equipment, exacerbating the damage inflicted by the shock. Additionally, faulty equipment can jeopardize the safety of individuals, such as when a scaffold becomes electrified or short circuits lead to fires.

Without a doubt, electricity has become an indispensable aspect of modern life, energizing various sectors such as industrial, manufacturing, commercial, and residential domains. The electricity industry encompasses the production, transmission, distribution, and supply of electricity to both the general public and industries. India's power sector is highly diversified, relying on conventional sources such as coal, gas, hydro, and nuclear power, as well as viable non-conventional sources like wind, solar, and agricultural and domestic waste.

Electric injuries pose a significant threat to individuals, as they can cause a range of multisystem trauma and complications, including cardiopulmonary arrest, cardiac arrhythmia, hypoxia, renal failure, and sepsis. These hazards can also lead to long-term neurological and psychosocial effects that can significantly affect an individual's quality of life. Studies conducted by Pliskin et al. (1994) and Noble et al. (2006) provide evidence of such effects. The primary injury events associated with electrical hazards are electric shocks and arc flash and arc blast. The former occurs when the victim comes into direct contact with electric current, while the latter involves an arc that carries electric current from the source to the victim without physical contact. This phenomenon can produce temperatures as high as 35,000° and can cause severe burns, hearing loss, eye injuries, skin damage from blasts of molten metal, lung damage, and blast injuries. Therefore, it is crucial to take appropriate measures to minimize electrical hazards and protect against electrical injuries. To this end, individuals and organizations must ensure they are knowledgeable about electrical hazards and take steps to prevent them, such as maintaining equipment and using appropriate personal protective equipment (Cooper & Price, 2002; Koumbourlis, 2002; Lee et al., 2000; Workplace Safety Awareness Council).

In consonance with the recent edition of 'Accidental Deaths and Suicides in India' 2021 [1], which was compiled by the National Crime Records Bureau (NCRB) under the auspices of the Ministry of Home Affairs, Government of India, it has come to light that the fatalities resulting from Other Causes, such as 'Electrocution,' witnessed an upswing in the year 2020 in comparison to the antecedent year, 2019. The State Crime Records Bureaux (SCRBx) collated the data for this report from the District Crime Records Bureaux (DCRBx) and furnished it to NCRB at the close of the year under review. The data from metropolises, defined as urban agglomerations with a population of ten lakh or more as per the latest census, is also collected separately. The report postulates that electrocution constituted 3.2% of the overall accident database for the year 2021, as evinced in Figure 1 [2].

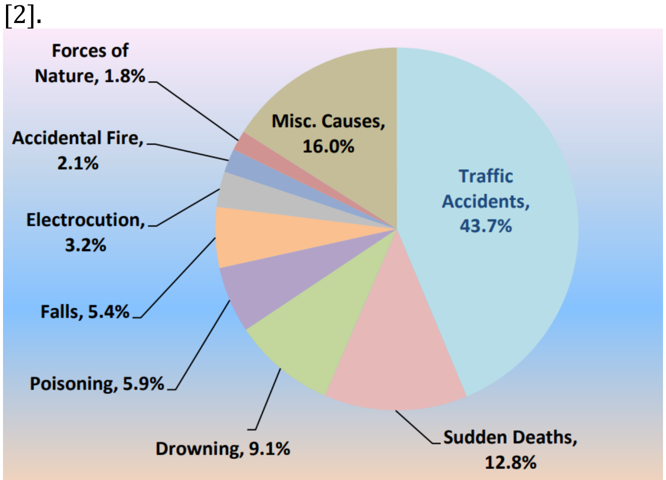


Fig -1: Percentage Share of Various Major Causes of Accidental Deaths during 2021

The chart representation in Figure 1 exhibits a category of causes that fall under the miscellaneous bracket. These miscellaneous causes comprise of an array of unfortunate events such as the collapse of a structure, suffocation, demise of expectant mothers, fatal attacks by animals, consumption of poisonous/illegal alcohol, accidental explosions, drug overdose, industrial machine accidents, firearm incidents, mines or quarry catastrophes, stampedes, air-crashes, ship accidents, and lastly, other causes that do not fall under the aforementioned categories or unknown causes altogether. These findings are in accordance with the research conducted by the concerned authorities on the subject matter (Ministry of Home Affairs, Government of India, 2019).

Table -1: Number and Share of Accidental Deaths due to Electrocution

S.No.	Cause	2019		2020		%
		No.	%	No.	%	Variation
1	Electrocution	13432	3.3	13446	3.7	0.1

The tabulated figures delineated in Table 1 [2] divulge the incidence of inadvertent fatalities brought on by electrocution in the years 2019 and 2020. The aforementioned data explicitly indicates a rise of 0.1% in the number of unintended deaths due to electrocution in the preceding year.

Table -2: Number of Persons Injured and Died due to Electrocution during 2020

S.No.	Cause	No.	Persons injured			Persons Died		
			Male	Female	Total	Male	Female	Total
1	Electrocution	13432	210	35	245	11402	2043	13446

In Table 2 [2], we can discern the grievous impact of electricity by examining the number of persons injured versus the number of persons who perished due to electrocution in India during the year 2020. However, it is important to note that minor injuries resulting from electrocution are not included in the report as they are not reported anywhere. Furthermore, the number of male fatalities due to electrocution is significantly higher than that of their female counterparts. This is a result of the male-dominated workforce that exists in industrial and other sectors.
When evaluating electrical safety, it is imperative to refer to various standards such as the National Building Code 2006 – Electrical Part, the Electricity Rules, and the appropriate sections of the NFPA 70 (an American standard) Edition 2011, particularly in areas that are deemed high-risk, including grounding, main and sub distribution boards, circuit protections, receptacles, hand-tools, and the like. Employing an electrical assessment for safety is crucial in Occupational Health & Safety Management System Standards, and for demonstrating due diligence to Occupational Health & Safety Regulations. By utilizing such a system, potential electrical hazards can be identified and subsequently prevented to minimize the loss of life and property.

2. PROBLEM IDENTIFICATION

In order to lay the foundation for the research with a problem statement, a visit to powerplant was made. The visit provided exposure to real working environments along with a practical perspective of a theoretical concept relevant to electrical hazards. Few significant benefits of the conducting a visit are given below:

- A chance to meet industry leaders, professionals, entrepreneurs, policymakers, and corporates who share their wisdom, learning, and experiences.
- To see and experience real layout and installation of electrical systems and interact with highly trained and experienced personnel.
- To learn about company policies in terms of production, quality, and service management.
- To open many doors for corporate training and internships, which in turn increase the employability.

- To understand how managers, engineers, employees work in tandem to achieve a common target, which is a management lesson in itself.
- To identify the learning towards safety and to decide future work areas like electrical safety, Construction safety etc.

There are some deficiencies in the electrical system of the "Powerplant", which are listed below for appropriate correction and corrective actions. These form part of the total number of non-conformities which will be further presented from the pictures of the various parts of the system and DB schedule as well as through the interpretations of the thermal images of the parts of the systems. All materials including the raw data forms part of the reporting package.

Observation 1.1 (Highly Hazardous):

Although single line diagram (SLD) of main distribution circuit and floor levels circuits connecting electrical loads (machines/lights/cooling system etc.) are available at site but does not match with actual circuit from floor level Distribution Boards to load points and therefore are not very useful.

With the help of proper electrical drawings, any addition/deduction/isolation of loads can be done easily and any table-top decision can be made centrally taking consideration of safety, integrity and good productivity.

Observation 1.2 (Hazardous):

Electrical Layout drawings are not available at site. Proper layout drawing is very important for the production-oriented factory. A layout drawing should be prepared considering possible maximum loading/production capacity of a floor area. Accordingly, electrical infrastructure will have to be built. In such a case any addition or deduction can be done easily and safely.

Observation 1.3 (Critical):

Periodical Insulation Resistance Test (IR Test) shall have to be carried out for all electrical equipment with Meggar applying 0.5 KV or 1 KV (according to the voltage rating of equipment). No such programmed schedule or record of Periodical Insulation Resistance Test is evident here.

Observation 1.4 (Critical):

Operating Test (measurement of load current) is needed on all feeders to monitor the condition and tendency of the equipment. No such programmed schedule or record of current load measurement is evident here.

Observation 1.5 (Hazardous):

Some of the Hand-held tools used by the electricians at floor level are not of good quality and are not double insulated. Hand gloves are missing in some floors and earthing lids are not found at any floor. For safety, double insulated hand-held tools, hand gloves and earthing lids are required.

Observation 1.6 (Hazardous):

Calibration/validation of all type of meters at floor levels, Substation and Generator Room should be done periodically. Calibration was never done after installation. Metering error of more than 3% not allowed in Act-2003.

Observation 1.7 (Hazardous):

The presence of lightning protection system but no drawing available: The "as built" electrical drawing (SLD) for lightning protection system was not available to review and so the adequacy and functionality of the system could not be checked.

Observation 1.8 (Critical):

Clear identifications/markings are not available at LT-PANEL, MDBs, DBs and SDBs. As per act, clear and permanent identification markings are required to be painted in all distribution boards, sub main boards and switchboards as necessary

Observation 1.9 (Hazardous):

Indicator lamps for some of the LT-PANEL/MDB/DB/SDB connected without any protective device (Fuse/MCB).

Observation 1.10 (Critical):

List and diagram (SLD) of the circuits that the distribution boards (SDB/DB/MDB/LT-PANEL) control are not available. This is a violation of Act-2003 which requires "Each (Distribution Board) shall be provided with a circuit list giving diagram of each circuit which it controls and the current rating for the circuit and size of fuse element."

Observation 1.12 (Highly Hazardous):

Means of identification of earthed conductors and earthed neutral conductors shall be of permanent nature. Here it is not followed (Some DB). It is a violation of electricity rules 1937, Act-2003.

Observation 1.13 (Highly Hazardous):

Circuits in most of the distribution boards (DB/MDB/SDB) as listed below have inadequate ECC (earth continuity conductor). This is a violation of Act-2003.

As per act-2006, ECC size shall not be less than half the area of the largest current carrying conductor supplying the line. If the phase conductor is less than 16 mm2 then ECC will be same size but not less than 14 SWG (3.243 mm2) and if the size is 16 to 35 mm2 then ECC will be 16 mm2

Observation 1.14 (Hazardous):

The size of neutral of the following circuits could not be measured due to absence of the means of individual circuit identification.

Observation 1.15 (Critical):

Higher rated MCCB/MCB/Fuse is used to protect the lower rated cable of circuits in the Distribution Boards listed below. This is a violation of Act-2003.

Moreover, the size of the protecting devices (MCCB/MCB/Fuse) of the circuits as listed below could not be registered in the DB schedule because their ratings are erased:

Observation 1.16 (Critical):

No protective device (MCCB/MCB) used for the following Circuits. This is a violation of Act-2003.

Observation 1.17 (Critical):

Unknown load is connected to the following DBs. This is a violation of Act-2003.

Observation 1.18 (Highly Hazardous):

Load current must be measurable in all circuits. But in some board's circuits are so cramped to measure the load current. The circuits whose load currents couldn't be measured are listed below: This is a violation of Act-2003.

Observation 1.19 (Critical):

Sockets & Lights are used in same circuit in the Distribution Boards listed below. This is a violation of) of Electricity Act-2003. As per Act-2003, Socket Circuit and Light Circuit shall be separated.

Pictorial Observations:

	
Category: **Highly Hazardous Observation B-1**	**Category:** **Highly Hazardous Observation B-2**
Location: Gas Generator, G.F, Generator Room,	**Location:** Gas Generator, G.F, Generator Room
Observation: Generator's battery terminal open. May cause electric shock, short circuit and fire.	**Observation:** Generator's self-starter's connection terminal open. May cause electric shock, short circuit and fire.
Required Action: Need to put terminal cover.	**Required Action:** Need to put terminal cover.

	
Category: **Highly Hazardous Observation B- 3**	**Category:** **Highly Hazardous Observation B- 4**
Location: Diesel Gen, G.F, Generator Room.	**Location:** Diesel Gen, G.F, Generator Room.
Observation: Generator's battery terminal open. May cause electric shock, short circuit and fire.	**Observation:** Generator's self-starter's connection terminal open. May cause electric shock, short circuit and fire.
Required Action: Need to put terminal cover.	**Required Action:** Need to put terminal cover.
	
Category: **Highly Hazardous Observation B- 5**	**Category:** **Highly Hazardous Observation B- 6**
Location: LT-3, G.F, Sub-Station Room	**Location:** LT-2, G.F, Sub-Station Room.
Observation: Un-terminated wire inside the panel. May cause electric shock.	**Observation:** Bottom of the panel has opening. Lint, dust and vermin may enter inside and cause short circuit & fire.
Required Action: Need to remove from the panel.	**Required Action:** Need to make the panel lint, dust and vermin proof
	
Category: **Highly Hazardous Observation B- 7**	**Category:** **Highly Hazardous Observation B- 8**
Location: LT-2, G.F, Sub-Station Room	**Location:** LT-3, G.F, Sub-Station Room
Observation: Lint and dirt present inside the panel. May catch fire.	**Observation:** Lint and dirt present inside the panel. May catch fire.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 05 | May 2023 www.irjet.net p-ISSN: 2395-0072

Required Action: Need to clean	**Required Action:** Need to make the panel lint, dust and vermin proof.
	
Category: **Highly Hazardous Observation B- 9**	**Category:** **Highly Hazardous Observation B- 10**
Location: LT-1, G.F, Sub-Station Room.	**Location:** LT-4, G.F, Sub-Station Room
Observation: Bottom of the panel has opening. Lint, dust and vermin may enter inside and cause short circuit & fire.	**Observation:** Bottom of the panel has opening. Lint, dust and vermin may enter inside and cause short circuit & fire.
Required Action: Need to make the panel lint, dust and vermin proof	**Required Action:** Need to make the panel lint, dust and vermin proof.
	
Category: **Highly Hazardous Observation B- 11**	**Category:** **Highly Hazardous Observation B- 12**
Location: LT-4, G.F, Sub-Station Room	**Location:** LT-4, G.F, Sub-Station Room
Observation: Bunch of cable connected at earth bus-bar. May cause loose connection, electric shock, spark and fire.	**Observation:** Connection without lug at earth bus-bar. May cause electric shock, spark & fire.
Required Action: Need to connect single cable in single Port.	**Required Action:** Need to use proper size cable lugs.
	
Category: **Highly Hazardous Observation B- 13**	**Category:** **Highly Hazardous Observation B- 14**
Location: PFI, G.F, Sub-Station Room	**Location:** PFI, G.F, Sub-Station Room
Observation: Lint and dirt present inside the panel. May catch fire.	**Observation:** Bottom of the panel has opening. Lint, dust and vermin may enter inside and cause short circuit & fire.

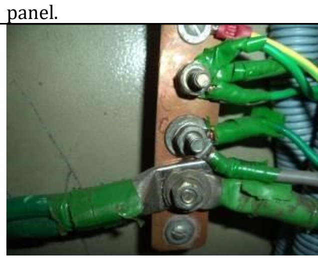
Required Action: Need to clean	**Required Action:** Need to make the panel lint, dust and vermin proof.

	
Category: **Highly Hazardous Observation B- 15**	**Category:** **Highly Hazardous Observation B- 16**
Location: COS-2, G.F, Sub-Station Room.	**Location:** COS-3,G.F, Sub-Station Room.
Observation: Lint and dirt present inside the Change-OverSwitch. May catch fire.	**Observation:** Bottom of the panel has opening. Lint, dust and vermin may enter inside and cause short circuit & fire.
Required Action: Need to clean lint and/or dirt.	**Required Action:** Need to make the panel lint, dust and vermin proof.
	
Category: **Highly Hazardous Observation B- 17**	**Category:** **Highly Hazardous Observation B- 18**
Location: TG #2	**Location:** Boiler # 2, 12mtr
Observation: Unwanted and hanging rebar found at TG # 2, 40mtr	**Observation:** Connections without lug at live neutral bus-bar. May cause loose connection, spark and fire.
Required Action: Removal of the protruding rebar	**Required Action:** Need to use proper size cable lugs. panel.
	
Category: **Highly Hazardous Observation B- 19**	**Category:** **Highly Hazardous Observation B- 20**
Location: MDB-2, IPS Room, G.F, Old Building	**Location:** MDB-2, IPS Room, G.F, Old Building
Observation: Bunch of cable connected at earth bus-bar. May cause loose connection, electric shock,	**Observation:** Panel door fixed by nut-bolts. Emergency operation difficult.

spark and fire.	
Required Action: Need to connect single cable in single Port.	**Required Action:** Need to use hinge-type door

	
Category: **Highly Hazardous Observation B-21**	**Category:** **Highly Hazardous Observation B-22**
Location: SDB-1, IPS Room, G.F, Old Building	**Location:** SDB-1, IPS Room, G.F, Old Building
Observation: Access limited to panel. Maintenance and emergency operation difficult.	**Observation:** Bunch of cable connected at earth bus-bar. May cause loose connection, electric shock, spark and fire
Required Action: Need to ensure clear access in front of the panel.	**Required Action:** Need to connect single cable
	
Category: **Highly Hazardous Observation B- 23**	**Category:** **Highly Hazardous Observation B- 24**
Location: SDB-1, IPS Room, G.F, Old Building	**Location:** SDB-2, IPS Room, G.F, Old Building
Observation: Bunch of cable connected at live neutral busbar. May cause loose connection, spark and fire	**Observation:** Access limited to panel. Maintenance and emergency operation difficult.
Required Action: Need to connect single cable in single Port.	**Required Action:** Need to ensure clear access in front of the panel.
	
Category: **Highly Hazardous Observation B- 25**	**Category:** **Highly Hazardous Observation B- 26**
Location: SDB-3, IPS Room, G.F, Old Building	**Location:** DB-1, G.F, Old Building, Section
Observation: Bunch of cable connected at live neutral busbar. May cause loose connection,	**Observation:** Bunch of cable connected at earth bus-bar. May cause loose connection,

spark and fire.	electric shock, spark and fire.
Required Action: Need to connect single cable in single Port.	**Required Action:** Need to connect single cable in single Port. panel.

	
Category: **Highly Hazardous Observation B-27**	**Category:** **Highly Hazardous Observation B-28**
Location: DB-1, G.F, Old Building, Section (South Side)	**Location:** DB-2, G.F, (South Side)
Observation: Bunch of cable connected at live neutral busbar. May cause loose connection, spark and fire.	**Observation:** Access limited to panel. Maintenance and emergency operation difficult.
Required Action: Need to connect single cable in single Port.	**Required Action:** Need to ensure clear access in front of the panel.
	
Category: **Highly Hazardous Observation B-29**	**Category:** **Highly Hazardous Observation B-30**
Location: DB-2, G.F, South Side	**Location:** DB-2, G.F, (South Side)
Observation: Bunch of cable connected at live neutral busbar. May cause loose connection, spark and fire.	**Observation:** Connections without lug at live neutral bus-bar. May cause loose connection, spark and fire.
Required Action: Need to connect single cable in single Port.	**Required Action:** Need to use proper size cable lugs. panel.
	
Category: **Highly Hazardous Observation B-31**	**Category:** **Highly Hazardous Observation B-32**
Location: G.F, Sub-Station Room.	**Location:** MDB-1, G.F, IPS Room, Old Building
Observation: Cable on the Cable Tray not dressed properly. May cause problem in identification and	**Observation:** Bunch of cable connected at earth bus-bar. May cause loose connection, electric shock,

maintenance.	spark and fire.
Required Action: Need to dress up properly.	**Required Action:** Need to connect single cable in single Port.
	
Category: **Highly Hazardous Observation B-33**	**Category:** **Highly Hazardous Observation B-34**
Location: TG # 3, 24mtr	**Location:** Reheat line unit # 1, 18mtr.
Observation: Temporary support found	**Observation:** Damaged insulation sheet and small opening found
Required Action: Removal of the temporary support and replacement with permanent support.	**Required Action:** Damaged insulation sheet needs to be repaired.

3. METHODOLOGY

3.1 HIRAC (Hazard Identification, Risk Assessment and Control)

With the advancement of new technology, techniques and machineries in construction of rural road, new and novel hazards are arising promptly. In order to achieve the target of constructing road within the stipulated time duration, a lot of hazardous activities are neglected and human lives are being put at stake daily. To control the hazards arising during construction of roads most of the contractors follow ISO 45001:2018 Occupational Health & Safety Management System in India, Factories act 1948 and rules as per the construction work. In most of the rules requires Hazard Identification, Risk Assessment and Control (HIRAC) to be performed for managing and controlling the hazards and minimizing the risk associated with the work.

It is legal requirement for all contractors to assess the risk and eliminate or minimize the risk failing to do so attracts enforcement actions. So Hazard Identification, Risk Assessment and Control must be performed where risk assessment is carried out for all potential hazards to achieve zero accident in construction industry

There are five basic steps to perform Hazard Identification, Risk Assessment and Control:

a) Hazard Identification

Hazard identification is the first activity to be performed by a competent team by thoroughly analyzing all the tasks and considering previous accident record, first aid cases, enforcement actions and occupational diseases data. The team identifying the hazard must include engineers, safety supervisors, workers and operation specialist.

In this stage, worksite analysis of work activities is carried out, this includes making a list of people to be involved, responsibility to be assigned, detailed work procedures in chronological order, materials required, loading and unloading location, equipment's to be used etc. For this various information's are required such as organizational charts, interviews, records and a 'walk-through' survey of the work site. A walk-through survey is considered to be the most effective way of listing out all the activities and possible failures at site. After analyzing and listing out everything necessary for completion of the activity, hazard identification is carried out. The goal of hazard identification is to find out potential risks associated with the hazard. The hazards identified during this stage is to be categorized on the basis of their nature, likelihood, severity and risk level. The list of identified hazards needs to be updated and reviewed in regular intervals.

b) Risk Assessment

Risk assessment is the second step in HIRAC in which the level of risk associated with the identified tasks are examined. In this step, a competent risk assessment team having expertise in hazards considers each and every tasks individually and determines the likelihood of the occurrence of hazards and its potential consequences on workers, property, business and environment. Previous accident data is also referred to draft the best possible assessment which is recorded and reviewed regularly. This assessment of risk helps us to determine the seriousness of the risk and its consequences link to the corresponding task.

After identifying the hazards, risk associated with the hazard is estimated by considering number of people exposed to each hazard and exposure time. Thus the probability and severity of harm that can be caused by a hazard is estimated. Meanwhile in order to find out the probability and severity of harm, knowledge of the regulations and safety standards under which the facility operates is also important, as some of the regulations provide guidelines about risk assessment procedure.

In the methodology adopted to assess risk quantitative techniques is used. Quantitative risk estimation (QRA) uses numerical values to express both the likelihood and consequences of an accident / incident that is likely to occur. It also involves intensive mathematical calculations and modelling to rank risk; such as low, medium, high. It describes risk as the frequency of injury or death. The risk is calculated considering the potential consequences of an incident / accident, the exposure factor and probability factor. The legends used to describe the likelihood/probability in the project is shown in Table 3.

Table 3: Probability Description

Value	Guide word	Description
1	Rare	Only in some exceptional circumstances
2	Unlikely	Very unlikely but remotely possible

3	Possible	The event may occur at some time
4	Likely	The event will probably occur in most circumstances
5	Almost Certain	The event is almost certain to occur and has occurred in repeatedly in the construction industry

The legends used to describe the consequences/severity of hazards in the project is listed in Table 4

Table 4: Severity Description

Value	Guide word	Result of hazard to personnel / Environmental impact
1	Insignificant	No injuries/ damage
2	Minor	Injury or illness requiring first-Aid treatment/ minor pollution
3	Moderate	Non-Reportable Lost Time Injury or Illness resulting in less than two days off work
4	Major	Reportable injury or illness resulting in more than two days off work/ Permanent Total Disability/ Major pollution
5	Catastrophic	Fatality

It is to be noted here that the higher value of likelihood or severity is to be selected always.

c) Risk Analysis

In this step again risk assessment sheet is considered and risk ranking is provided to every activity. Prioritization of risk aids in highlighting the hazards that should be undertaken as a priority for emergency management program. The risk ranking is based on occurrence probability of hazard and its potential consequence arranged to form a risk matrix system.

Risk matrix is a quantitative tool that is used to evaluate and analyses the risk level and to rank the risk according to their severity & probability. According to ISO 45001:2018, preparation of risk matrix is an integral part of the risk assessment process. The rows and columns in the risk matrix are the likelihood and consequences of the hazardous activity undertaken respectively.

Risk (R) = Likelihood (L) × consequences (C)

Or

Risk (R) = Probability (L) × severity (S)

The absolute risk attained after preparation of risk matrix is simply the product of likelihood/probability of occurrence and consequences/severity of hazard. After the determination of likelihood and severity value, risk level is determined by the help of risk matrix as shown in Table 3. The intersection of rows (Likelihood) and columns (Severity) indicates the risk level of the task undertaken.

Table 5: Risk Matrix

Risk matrix		Severity (S)				
		1	2	3	4	5
Probability (P)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

d) Control Measures

Control measure involves any system, procedure, device or process that is intended to eliminate the hazards or to reduce the severity of consequences of any accident that does occur.

Based on the risk rating attained in the risk matrix, the risk level is determined as shown in Table 4 and on the basis of risk level corresponding control measures are selected to reduce the risk to an acceptance level. This reduction is to be achieved by reducing the likelihood and/ or severity by the implementation of control measures.

Table-6: Recommended action plans against different risk levels

Risk Rating (P XS)	Risk level	Recommended Action Plan/ Implementation
1 to 3	Moderate / Low risk	No additional risk control measures may be needed.
4 to 8	Average / Medium risk	Work can be carried out with risk controls on site
9 to 16	Excessive / High risk	Don't start work, the risk level must be reduced to low/medium level before commencing work.
16 to 25	Very high risk	Unacceptable

The controls measures recommended for the attained risk level from the previous step is based on the concept of "hierarchy of controls" in which the objective to reduce the risk level by implementing measures like elimination, substitution, isolation, Engineering controls and administrative controls and lastly PPEs. Figure 1, illustrates the control hierarchical model adopted in methodology for determining the control measures. [4]

In the occupational health and safety context, risk control is done by using the "risk control hierarchy" methodology. This hierarchy helps to decide on which risk control to implement. The preference of selecting the risk control option is arranged in a hierarchical manner from top to bottom.

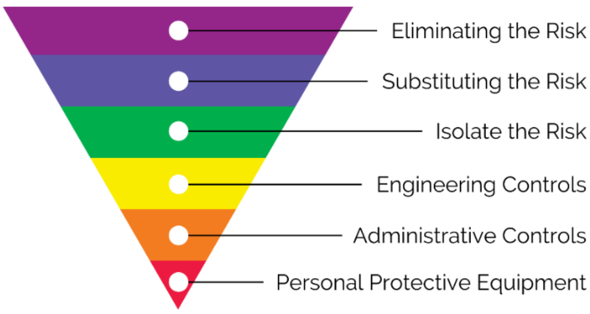


Figure 2: Hierarchy of controls [4]

(i) Elimination – In the elimination part, we will try to eliminate the hazard which can remove the cause of danger completely. However, it is difficult to eliminate all hazards and unsafe conditions, and therefore elimination is not always possible

(ii) Substitution – In the substitution part, we will try to find a substitute, if we can't eliminate the hazard completely, by finding a substitute it will be less risky to achieve the same outcome.

(iii) Isolation – In Isolation control measure, some form of barrier is placed between the employee and the hazard in order to provide protection. The risk is always there but by providing the barrier, workers are shielded by the hazard.

(iv) Engineering Control – In engineering control, we can implement the engineering techniques to reduce the risk of the hazards such as doing any physical changes, adding safe guards etc.

(v) Administrative Control - In administrative control, the administrative works should be followed up properly such as proper training to the employees & workers, risk assessments, issue of permits etc.

(vi) PPE (Personal Protective Equipment) – This is the final stage, here proper PPE to be provided to the employees and workers to save themselves from the hazards.

e) Monitor and Review

All the updated Hazard Identification, Risk Assessment and Control have to be monitored and reviewed by management and competent staff at regular interval.

3.2 Analytic Hierarchy Process (AHP)

Thomas Saaty in the year 1980 developed a tool that is used to make complex decisions and to help the decision maker for setting-up the priorities. Using AHP tool both objective as well as subjective aspects of decision making can be captured by plummeting complex decisions into a succession of pairwise comparisons which is synthesized later to obtain the results. The biasness of the decision maker is reduced in AHP by checking the results for consistency. [5]

The steps involved in the implementation of AHP are

1)Computing the vector of criteria weights.

2) Computing the matrix of option scores.

3) Ranking the options.

It is to be assumed initially that 'm' evaluation criteria are considered, and 'n' options are to be evaluated.

3.2.1 Computing the vector of criteria weights

In order to calculate the weights for the several criteria, a pairwise comparison matrix A is developed in the first step of AHP. The matrix A is a m×m real matrix, where m is the number of evaluation criteria considered. For a matrix A, a_{jk} denotes the entry in the jth row and the kth column of A. Each entry a_{jk} of the matrix A represents the importance of the ith criterion relative to the kth criterion.

If $a_{jk} > 1$, then the jth criterion is more important than the kth criterion, while if $a_{jk} < 1$, then the jth criterion is less important than the kth criterion.

If two criteria have the same importance, then the entry $a_{jk} = 1$. The entries a_{jk} and a_{kj} satisfy the following constraint:

$$a_{jk} . a_{kj} = 1$$

Obviously, $a_{jj} = 1$ for all j. The relative importance between two criteria is measured according to a numerical scale from 1 to 9, as shown in Table 1, where it is assumed that the jth criterion is equally or more important than the kth criterion. Values 2,4,6 and 8 can be used to represent the intermediate intensity.

Table 7: Interpretation of values for construction of pair wise matrix

Value of a_{jk}	Interpretation
1	Both the hazards are equally hazardous
3	Hazard 'j' is slightly more hazardous than hazard 'k'
5	Hazard 'j' is more hazardous than hazard 'k'
7	Hazard 'j' is strongly more hazardous than hazard 'k'
9	Hazard 'j' is absolutely more hazardous than hazard 'k'
2,4,6,8	Intermediate values

Once the matrix A is built, it is possible to derive from A the normalized pairwise comparison matrix A_{norm} by making equal to 1 the sum of the entries on each column, i.e. each entry a_{jk} of the matrix A_{norm} is computed as

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^{m} a_{lk}} \qquad (1)$$

Finally, the criteria weight vector w (that is an m-dimensional column vector) is built by averaging the entries on each row of A_{norm}, i.e.

$$w_j = \frac{\sum_{l=1}^{m} \bar{a}_{jl}}{m} \qquad (2)$$

3.2.2 Computing the matrix of option scores

The matrix of option scores is a n×m real matrix S. Each entry s_{ij} of S represents the score of the i^{th} option with respect to the j^{th} criterion. In order to derive such scores, a pairwise comparison matrix $B^{(j)}$ is first built for each of the m criteria, j=1,...,m. The matrix $B^{(j)}$ is a n×n real matrix, where n is the number of options evaluated. Each entry $b_{ih}^{(j)}$ of the matrix represents the evaluation of the i^{th} option compared to the h^{th} option with respect to the j^{th} criterion.

If $b_{ih}^{(j)} > 1$, then the i^{th} option is better than the h^{th} option, while if $b_{ih}^{(j)} < 1$, then the i^{th} option is worse than the h^{th} option. If two options are evaluated as equivalent with respect to the j^{th} criterion, then the entry $b_{ih}^{(j)}$ is 1. The entries $b_{ih}^{(j)}$ and $b_{hi}^{(j)}$ satisfy the following constraint:

$$b_{ih}^{(j)} = b_{hi}^{(j)} = 1$$

and $b_{ii}^{(j)} = 1$ for all i. An evaluation scale similar to the one introduced in earlier Table may be used to translate the decision maker's pairwise evaluations into numbers.

Second, the AHP applies to each matrix $B^{(j)}$ the same two-step procedure described for the pairwise comparison matrix A, i.e. it divides each entry by the sum of the entries in the same column, and then it averages the entries on each row, thus obtaining the score vectors $s^{(j)}$, j=1,...,m. The vector $s^{(j)}$ contains the scores of the evaluated options with respect to the j^{th} criterion. Finally, the score matrix S is obtained as

$$S = [s^{(1)} \dots s^{(m)}] \quad (3)$$

3.2.3 Ranking the options

Once the weight vector w and the score matrix S have been computed, the AHP obtains a vector v of global scores by multiplying S and w, i.e.

$$v = S\,w \quad (4)$$

The i^{th} entry vi of v represents the global score assigned by the AHP to the i^{th} option. As the final step, the option ranking is accomplished by ordering the global scores in decreasing order.

4. RESULT

All the 34 identified electrical and other major fault scenarios are evaluated using AHP, where n=34 alternatives. Each identified findings (F) (criterion) is expressed by an attribute. The larger value of the given attribute, results into better enactment of the alternative with respect to the corresponding finding (F).

Initially, the investigator prepares the pairwise comparison matrix A as discussed in Chapter 4 for the 34 identified findings (F) in which both the rows and columns represent the findings using the values for construction of pair-wise matrix.

After completing the matrix, weight of each finding is calculated using eq. (1) and eq. (2). Then the calculated weight value is multiplied with the obtained matrix to get the ranking as discussed in the methodology section.

Using the pairwise comparison matrix the score matrix in formed to determine the weight of each hazard. The final raking of the hazards obtained after the multiplication of weight values with the score matrix.

Table 8 Rank of the findings using AHP

	TOTAL	AVERAGE	Consistency Measure	Rank
B-01	0.90	0.0264	47.46	16
B-02	0.87	0.0257	46.65	22
B-03	0.88	0.0259	46.98	20
B-04	0.93	0.0274	48.13	12
B-05	0.49	0.0145	55.46	2
B-06	0.33	0.0098	49.85	7
B-07	0.31	0.0092	48.68	11
B-08	0.29	0.0085	46.24	25
B-09	0.85	0.0249	47.18	19
B-10	0.51	0.0151	55.20	3
B-11	1.11	0.0327	44.33	28
B-12	1.21	0.0355	50.68	6
B-13	0.25	0.0073	43.04	32
B-14	0.28	0.0083	46.76	21
B-15	0.29	0.0087	47.54	14
B-16	0.25	0.0075	43.46	30
B-17	0.55	0.0163	59.21	1
B-18	1.08	0.0319	43.87	29
B-19	1.32	0.0387	47.41	17
B-20	1.31	0.0386	47.39	18
B-21	1.20	0.0353	51.28	5
B-22	1.52	0.0447	49.84	8
B-23	1.38	0.0407	46.49	24
B-24	0.88	0.0258	53.01	4
B-25	1.26	0.0372	47.51	15
B-26	1.14	0.0336	45.74	26
B-27	1.54	0.0453	47.94	13
B-28	0.90	0.0264	49.26	9
B-29	1.00	0.0295	42.98	33
B-30	1.06	0.0311	39.97	34
B-31	1.74	0.0513	48.81	10
B-32	2.37	0.0698	46.60	23
B-33	2.64	0.0777	45.69	27
B-34	1.30	0.0383	43.07	31
		CI	0.42	
		RI	1.66	
		C.Ratio	0.3	

The ranking attained from the above table is categorized on the basis of their corresponding consistency measure score. If the consistency measure is more than 50 then the corresponding finding from the electrical safety inspection is considered to have very high priority to be resolved by the provided recommendations whereas if the score is between 46 to 49 then it is considered to be of medium priority and if the score is less than 45 then it is considered to be having low priority to be resolved.

From the prioritization of findings obtained in Table 8, it can be clearly identified that the electrical fault that need immediate resolutions are:

Ranking	Findings
1	Unwanted and hanging rebar found at TG # 2, 40mtr
2	Un-terminated wire inside the panel. May cause electric shock.
3	Bottom of the panel has opening. Lint, dust and vermin may enter inside and cause short circuit & fire
4	Access limited to panel. Maintenance and emergency operation difficult.
5	Access limited to panel. Maintenance and emergency operation difficult.

Tool box talk / PEP talk were delivered on the basis of observation during safety survey. The talk covered all the aspects of maintaining safer and healthy working environment. Few important talk included the training on electrical safety, training on work at height, training in fire, training on scaffolding, air & noise monitoring and mock drill at site.

Figure 3 PEP Talk Conducted near Boiler # 1

3. CONCLUSIONS

The research sets out the result of investigation performed to identify different electrical safety faults and their remedial measures in a power plant and the following conclusions can be derived from the results.

- The methodology adopted in the research uses checklist method to identify the electrical safety hazards in the industry. Based on the experience of the author, checklist method can be highly useful if it is periodically implemented and most importantly updated based on new findings.

- It was also observed during the discussion with industrial workers that they were not given any separate electrical safety training apart from the general safety drill.

- Another tool used in the prioritization of identified electrical flaws in the system is AHP which a very comprehensive comparative tool used to compare each finding with others to determine their importance. Looking at the results, it can be concluded that AHP should only be applied to tasks where pair-wise comparison matrix is of order 10 X 10 or less since, the task of comparing each mode with all the other possible finding is very tedious and laborious for a group to perform with perfection.

Overall, it can be concluded that the adopted methodology provides an upright technique to determine the flaws and to set the priority in order to minimize the risk by implementing provided recommendations.

In the current research, only electrical related process was covered in-detail for identification of flaws during the working of plant. In the future research, all the tasks and process involved in the textile industry can be investigated with different analytical tools providing overall safety status.

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