Development of Proactive Mine Electrical Safety Management System (MESMS) for Indian Underground Hard Rock Mines: A Risk Assessment Based Approach

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Abstract

Automation of operational activities in trackless underground hard rock mines is very common and necessary trend in present day Indian mining scenario. The use of various types of electrical machineries and equipments like electro-hydraulic drill jumbo, electrically operated LHD (Load haul Dump), auxiliary and booster ventilation fans, winding system and pumping system etc. are essential requirements for carrying out mining operations efficiently and safely. Beside this, mine Illumination system comprises large number of electrical components. As the use of the electricity is indispensable in nature and exposure of miners to the electrical equipments is increasing day- by- day, the occurrence of electricity related accidents in mining industry is also increasing. In this context, a detailed study on recent accident/incidents caused by electrical installations in mines and associated hazardous issues in a trackless underground hard rock mine was conducted. The major outcomes of case study exhibited the necessity of a methodical approach using suitable scientific tools to moderate the hazards associated with the electrical equipments and installations during different unit operations in case study mine. As the measures of control, a proactive Mine Electrical Safety Management System (MESMS) has been established in accordance with the Directorate General of Mine safety (DGMS), India, guidelines, CEA (Central Electricity Authority) Regulation,2010, India and Hazard and Operability Analysis (HAZOP) procedure and instigated for implementation. In this paper; design and development of various components of MESMS viz. hazard identification and Risk assessment of electrical equipment operations and maintenance activities, Standard Operating Procedures (SOP) for significant hazards and apposite work plans (WP) to accomplish the goal of operational safety have been demonstrated.

Keywords
Mine Electrical Safety Management System (MESMS), Directorate General of Mine safety (DGMS), CEA (Central Electricity Authority), Hazard identification, Risk assessment, work plan

1. Introduction
In industries, the incidents or hazards can be categorized mainly into two distinct types, the electrical incidents and the non-electrical incidents, and the mitigation measures are based on the category of the incident aiming to minimize the risk of the incidents for future occurrences and reducing the probability of occurrences. This paper focused explicitly on electrical incidents in mining industries as the use of electrical equipment like mining tools, logistics and other numerous types of equipment in mining industries are very common these days. However, with such tremendous use of electrical equipment/tools on the other hand increases the chances of electrical hazards like electrical shock, fire eruptions due to electrical faults, and at extreme cases the explosions etc. Therefore, electrical safety has become one of the major concerns for mining industries.

The electrical hazards are very different from nonelectrical hazards and are very difficult to deal with as it is apparently very hard to envisage the level of hazard associated with an electrical circuit just by mare visual inspection of the circuit. For example, just by visual inspection, it is impossible to realize the voltage level of a conductor or a terminal with respect to the earth or ground potential, or how much current a conductor is carrying or whether a given circuit is energized or not, and hence the main cause of electrical hazards. Therefore, external indicators and measuring devices are must to monitor these parameters to have proper knowledge to avoid any lack in safety measures to evade any unexpected incident causing injury to the operator or in some cases even to loss of life of the operator, loss of property and the environmental affects as well. Moreover, accidents, whatever is the cause for the accident is, severely affect the production quantity and quality, production cost and the efficiency of the production in mining industries. Furthermore, since electrical equipment has become a practice in mining industries now, it is learnt over the years that the electrical shock to the operator working is not the only electrical hazard associated with electrical safety. For example, the major types of electrical hazards with high voltage electrical circuits are electric shock, fire or initiation of fire, flashover etc., whereas in lower voltage level electrical circuits like control circuits, sensing and measuring circuits, electrical hazards could lead to the failure of control circuit which eventually lead to the failure of the power circuit. Many a cases, due to lack of safety features and measures, such failure may lead to major safety hazards. Therefore, there is a need for safety procedure to be defined and followed in order to reduce the risk levels of the identified hazards to acceptable limit. Moreover, the mining industries now continue to emphasizing more on electrical safety in the workplace which necessitates and seeking guidelines to safety procedure in order to help the operators, the engineers and the technicians working in the mining industries. The aim of such procedure is to monitor and operate any electrical equipment in a safe manner to avoid any chances of major electrical hazards associated with the use of electrical power in mine operations. For example, a mine operator on assigned duty must consider the isolation procedure and reinstate the same to the normal conditions while positioning electrical equipment during its use. The operator should be trained and knowledgeable enough to assess the working conditions and, accordingly plan the installation and operation of the electrical equipment. This is to control and limit the chances of any electrical hazards.

In order to study the aspects and characteristics of electrical hazards and to device its safety measures, different studies were carried out in the past on different types of electrical hazards, assessing the safety believes and most importantly the safety and risk management. For example, Roberts(2014) discussed different types of electrical hazards and their causes in details. The work discussed by Boubaker, Mekni and Jerbi (2017)is related to the integration of Occupational Health & Safety Management System and risk management principles into electrical safety. The electrical safety beliefs and practices were assessed by Roy , Aswathy and Nair (2015) and it is observed that the electrical safety level score is 0.76 in 4 in Hail region of Saudi Arabia which absolutely low, indicating poor electrical safety culture. Therefore, with such assessments, it was tried to realize the levels of electrical safety awareness and safety measures. A study on electrical accidents and safety measures is presented by Ezennaya, Enemuoh and Agu in 2017 to showcase the intricacies in electrical safety issues. The primary aim of this study was to provide some basic knowledge about electrical hazards to help employees to ensure safe operating environment. Basak(2015), had portrayed an overview of basic electrical hazards and safety tips which were explained in details for home and work environment. This work helped the community and electricity users about concerns of electrical safety and its serious consequences, if not properly performed. A brief article on electrical safety is presented by Michael and Homce,2010 to illustrate several aspects of electrical hazards. Therefore, in recent trends it is observed that there is a consistent move towards the study on electrical hazards, its awareness and the safety measures.

As explained earlier, since the scope of this paper is made limited to the concerns of electrical hazards in mining industries, therefore the reference works dealing with the same is also studied in due course. For example, a research on Mining Electrical Safety, its legacy of protection against shock, fires, and explosions in the U.S mining industry is discussed in HSE Books (2015). A guideline to the use of electricity in mines is offered by Clay (2017), primarily aiming at mine operators, engineers, technicians and others employees on duty within the mining industries working below the ground. The aim of these guidelines is to control and limit the major electrical hazards in mines. However, since to control electrical hazards, there is a need for hazard identification and risk management, the same were studied and discussed by Roberts (2012),Clay(2017), and El-Shimy(2018) respectively.

The work presented in this paper is a detailed study on recent electrical hazards in mines and the associated hazardous issues in a trackless underground hard rock mine in India. The study concludes the necessity of systematic approach using suitable scientific tools to moderate the electrical hazards during different unit operations in case study mine. As a measures of control, a proactive Mine Electrical Safety Management System (MESMS) has been established in agreement with the Directorate General of Mine safety (DGMS), India, guidelines (DGMS 2016 and DGMS, 2019), CEA (Central Electricity Authority) Regulation, 2010, India and Hazard and Operability Analysis (HAZOP) procedure (Clay, 2017 and PQRI, 2014) and instigated for implementation. The design and development of different components of MESMS like hazard identification, risk analysis and risk assessment of electrical equipment operations and maintenance activities, Standard Operating

Procedure (SOP) for significant hazards and suitable work plans (WP) to accomplish the goal of operational safety is demonstrated. The devised risk management process ensures systematical identification and control of the risk.

1.1 Some Key Definitions in Risk Management

Some important terminologies are as follows:

a) **Electrical Hazard:** Failure of electrical equipment leading to electric shock or damage of property.
b) **Risk:** probability of occurrence of an electrical hazard.
c) Risk Score: value assigned to a risk.
d) **Risk assessment:** hazard identification, risk analysis and risk evaluation.
e) Hazard identification/Recognition: Listing and characterizing the hazards,
f) **Risk analysis:** determining the risk level and risk estimation
g) **Risk control:** actions to reduce the risk evaluation

2. Description of case study Mine

The Case Study Mine is a mechanized underground hard rock mine in eastern part of India with entry through 9^0 decline and vertical shaft. Latest technology of trackless mining system is practiced in this mine with decline as mine entry and ramps for access to the stopes. Present method adopted to excavate the ore from the case study mine is Horizontal Cut & Fill method. Various underground equipments used in the mine are Mine truck (MT)/Low Profile Dump Trucks (LPDT), Scoop truck (ST)/ LHDs, Service Transport Vehicles (STV) like Scissor lift, Passenger Carrier, and Explosive Van etc. Furthermore, mine is utilizing Electro-hydraulically operated Drill Jumbos; modern PLC controlled Koepe Winding System, three numbers of main ventilation fans, underground dewatering pumps, compressors and large number of auxiliary ventilation fans etc., These equipments and installations are mainly dependent on efficient surface and underground 'Power Distribution and Supply Management System' (PDSMS). Mine Illumination system also comprises large number of electrical components. These electricity dependent mine installations and equipments are made continuously operational by well-established mine PDSMS comprising Mine Main receiving stations(MRS) at surface, nine numbers of Underground Substations, apposite cable lay outs, numerous types of Breakers, Transformers and Power Distribution Boxes etc. In underground, the substations are established at each level to supply the required power to the working areas. The location wise details of underground substations in case study mine are shown in Table 1.

Table 1. Underground Substations

3rd Level	3 E(A) Sub station 3 E(B)Sub station
4th Level	Vertical Shaft-1 Sub station West- A Sub station
5th Level	Vertical Shaft -2 Sub station West- B Sub station
6th Level	Vertical Shaft- 3 Sub station West-C Sub station
7Th Level	Vertical Shaft- 4 Sub station

The record of numbers of electrical motors and their aggregate horse power are depicted at Table 2 demonstrate the utilization level of electric equipment in mine. In addition to this, mine electrical department is also taking care of approximately 6500 meters of high pressure cable and 23050 meters of medium pressure cable that had been laid for distributing the power to the various parts of mines.

In spite of cautious execution of traditional electrical safety management system in the case study mine, it has undergone 02 serious injuries, 12 reportable injuries (Injury that forces the employee to remain absent from work for more than 72 hrs.), 37 minor injuries due to electrical hazards, causing a loss of almost 387 number of man days' loss from January, 2014 to December, 2019. In addition to this, 77 numbers of near miss incidents have been reported to mine safety officer during last five years. So, there was a serious need to establish and implement a proactive hazard mitigation framework for electrical operations and maintenance works to enhance the safety performances.

Table 2. Numbers and aggregate horse power of electrical motors used in Mines

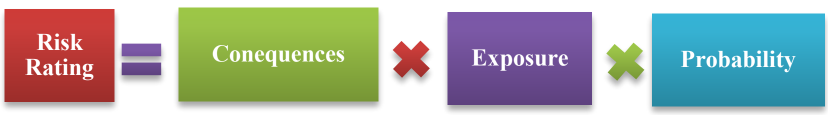
Locations	Number of units	Total H.P
Installed above ground		
winding	2	667
ventilation	3	1000
pumping	4	350
workshop	11	74
Main compressor	01	1000
Auxiliary compressor	01	150
Tugger hoist	01	20
Conveyor and vibrator	4	40
Installed below ground		
Ventilation(Auxiliary)	20	957.5
pumping	19	1222.5
Conveyor and vibrator	6	140
Drill Jumbos	7	585

.3. Development of Mine Electrical Safety Management System (MESMS) (Methodology)

Mine Electrical Safety Management System (MESMS) was framed as per the provisions substantiated in Directorate General of Mine safety (DGMS), India, guidelines, CEA(Central Electricity Authority) Regulation,2010, India and Hazard and Operability Analysis (HAZOP) procedure. Methodology followed for the development of MESMS is described below:

a) All hazards associated with different works/activities concerning electrical installations and equipment operations were recognized through the brainstorming session involving domain experts, safety professionals and experienced workmen.

b) Subsequently risk ratings of all hazards were calculated, so that the hazards could be classified as per risk score. The estimation of risk rating was done by assessing and enumerating the consequences, exposure and probability. The Scale for Rating is shown in table 3**.** The risk rating of a hazard was quantified by using the formula written below:



c) Risks were classified according to the level of risk i.e., highest to lowest, which empower one to establish risk which need immediate attention or may be managed by following routine procedures. Hazard classification criteria as per risk rating is shown as below:

Risk level >200	***Requiring immediate attention***
Risk level <200&>20	***Requiring Management Action***
Risk level <20	***To be watched and reviewed***

d) Acknowledged hazards with risk score more than 200, were considered as principle hazard / significant hazard

e) Next step involves the prediction of the hazard Mechanism, development of safety control structure to minimize the effect of the identified hazards.

f) Development of working protocol and SOP to mitigate the recognized hazards and judicious Implementation of working protocol.

4. Development of MESMS

In case study mine, electrical installation and equipment specific MESMS has been developed under the guidance of Head Safety of the mine and Engineering in-charge(Electrical) for ensuring healthy and safe working condition for the employees linked with mine electrical operation and maintenance. MESMS has been devised in accordance with the DGMS (Tech.) (S&T) circular No.5 dated 2/4/2016(DGMS, 2016), DGMS Technical Circular NO.03 of 2019(DGMS.2019), CEA (Central Electricity Authority) Regulation,2010, India and Hazard and Operability

Analysis (HAZOP) procedure (PQRI,2014 and Sinha, 2016). An apex level team with proficiency in electrical equipment operation and maintenance was formed and the methodology pertaining to formulation of MESMS was confirmed through literature study, statutory guidelines and investigation of past accident/incident records (As described in section 3). The process flow diagram at **Figure-1** is portraying various steps to frame MESMS.The foremost phase was to recognize all hazards associated with various operations/activities involving electrical installations. Next step involved assigning risk rating to all hazards, so that the hazards could be classified in accordance with risk score. The risk rating involved consequences of the associated hazard, its exposure and probability of such hazard in a process. The quantification of risk rating was done by quantifying the consequences, exposure and probability as per the methodology described in section 3. The Scale for risk rating and required abbreviations used in MESMS are illustrated in **Table-3** and **Table-4** respectively. A person in electrician capacity could now effortlessly discover which hazard is more significant for him by just looking at the chart of risk rating and thus serves an imperative tool of work sequence.

Table 3. Scale for Rating (as per DGMS (Tech.) (S&T) circular No.5 dated 2/4/2016)

Consequences	*Scale*	*Exposure*	*Scale*	*Probability*	*Scale*
Several dead	5	Continuous	10	May well be expected	10
One dead	1	Frequent (daily)	5	Quite possible	7
Significant chance of fatality	0.3	Seldom (weekly)	3	Unusual but possible	3
One permanent disability / less chance fatality	0.1	Unusual (monthly)	2.5	Only remotely possible	2
Many lost time injuries	0.01	Occasional (yearly)	2	Conceivable but unlikely	1
One lost time injury	0.001	Once in 5 years	1.5	Practically impossible	0.5
Small injury	0.0001	Once in 10 years	0.5	Virtually impossible	0.1
		Once in 100 years	0.02		
Risk Ratings = Consequences x Probability x Exposure					

Table 4: Abbreviation (as per DGMS (Tech.) (S&T) circular No.5 dated 2/4/2016)

➢ **RSP**: Relevant statutory provision's	➢ **DGC**: DGMS circulars
➢ **MG**: Management guidelines	➢ **ERCI:** Existing risk control index
➢ **RES:** Responsibility	➢ **MED:** Medium
➢ **REG:** Regulation of Metalliferous mines regulations,1961	➢ **GVTO:** Group Vocational Training Officer
➢ **SOP:** Standard operating procedure	➢ **HAZ:** Hazard
➢ **CONS**: Consequence	➢ **EXPS:** Exposure
➢ **PROB**: Probability	➢ **SSR:** Systematic Support Rule
➢ **MVTR**: Mine Vocational Training Rules 1966	➢ **MMR:** Metalliferous Mines Regulation 1961

A total number of 25 hazards allied with mine electrical works **(shown in Table- 5)** and maintenance were investigated by using the methodology described in section 3. Hazard identification, estimated risk rating and percentage of manpower exposed to particular hazards are shown in Table-5. The case study mines was found to be associated with 25 numbers of recognized hazards, among them 3 numbers of hazards were major and require immediate attention (Risk score ***>200***), 17 hazards require management action (Risk score ***<200&>20***) and 05 hazards were decided to be watched and reviewed (Risk score***<20***). After investigating overall accident phenomena, three major **hazards namely Electrical accident due to improper shutdown, Non-compliance of operating procedures and Contact with bare conductors with live electrical apparatus etc**. were analyzed further and mechanism of accident occurrences (i.e. the probable cause of accidents in form of equipment malfunctioning, human error, communicational fault etc.), their specific control system and procedure to be followed to prevent such occurrences had been specified. Details of one of such analysis regarding 'Electrical accident due to improper shutdown' having highest risk rating of 500 is exemplified in **Table 6 and Table** 7. **Table 7** also depicts the regulatory compliance required, Existing risk control index (ERCI: Represents the present status of controls and constraints) and persons responsible for the execution of particular procedure etc.

Table 5. Initial hazard identification for mine electrical installations and equipment

Electrical Installation (Work Sheet)						**Date: 15.08.2020**
Sl. No.	**Description of Hazard**	**% of workers exposed**	**Cons.**	**Exps.**	**Prob.**	**Risk Score**
1.	**Electrical accident due to improper shutdown****	Very Low, < 5 %	5	10	10	500
2.	Electrical shock due to non-identification of switchgears	Very Low, < 5 %	5	10	3	150
3.	**Non-compliance of operating procedures**	Very Low, < 5 %	5	10	7	350
4.	**Contact with bare conductors with live electrical apparatus**	Very Low, < 5 %	5	10	7	350
5.	Distinctions of the installations having provision of more than one incoming feeders not done	Very Low, < 5 %	5	5	7	175
6.	Back feed of electrical power	Very Low, < 5 %	5	5	7	175
7.	Accident due to fall of OH bare conductor.	Very Low, < 5 %	5	10	2	100
8.	Protections against lightning surges are not provided.	Very Low, < 5 %	5	2	10	100
9.	Over Head line maintenance	Very Low, < 5 %	1	10	10	100
10.	Electrical Earthing failure	Very Low, < 5 %	1	10	10	100
11.	Lack of knowledge on specifications and circuitry	Very Low, < 5 %	1	10	7	70
12.	Non operation of pilot core relay	Very Low, < 5 %	1	10	7	70
13.	Electrical shock due to water seepage and moisture	Very Low, < 5 %	1	5	7	35
14.	Identification of circuits of different voltages not done	Very Low, < 5 %	1	10	3	30
15.	Electrical accident due to damage of trailing cable.	Very Low, < 5 %	1	10	3	30
16.	Electrical equipment shifting	Very Low, < 5 %	0.3	10	10	30
17.	Cable laying and dressing	Very Low, < 5 %	0.3	10	10	30
18.	Fall of apparatus due to inadequate support.	Very Low, < 5 %	0.3	10	3	9
19.	Auto electrical works	Very low, <5 %	0.1	5	7	3.5
20.	Battery handling	Very Low, < 5 %	0.1	3	7	2.1
21.	Use of underrated apparatus/switchgears and cables	Very Low, < 5 %	0.01	10	7	0.7
22.	Excess heating of the electrical machineries	Very Low, < 5 %	0.01	10	7	0.7
23	Fire due to Short circuit	Very Low, < 5 %	5	10	3	150
24	Explosion at electrical install	Very Low, < 5 %	5	10	2	100
25	Spark/Splash	Very Low, < 5 %	1	5	10	50

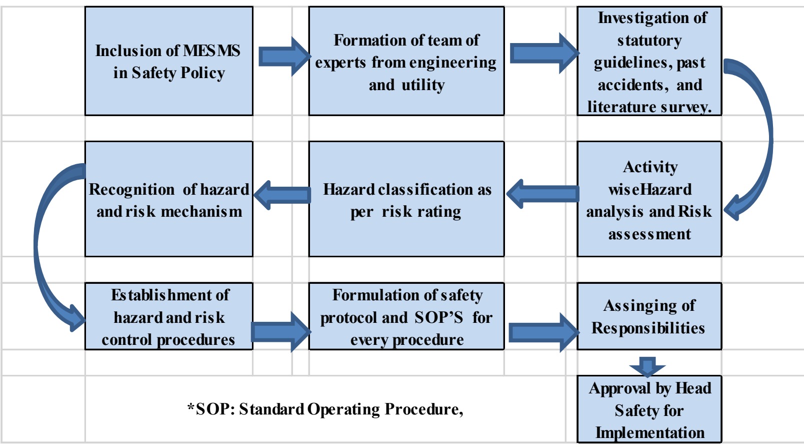


Figure 1. Various steps to frame MESMS

Table 6. Details Risk Assessment for Electrical accidents due to improper shutdown

Name of the Company: XXXX							
Name of the Mine: Case study underground hard rock mine							Date: 20.08.2020
Risk Assessment							
Hazard: Electrical accidents due to improper shutdown							
Haz. No.	Hazard	Mechanisms	Calculated Risks				Comments
			Cons.	Exps.	Prob.	Risk Score	
EISH-1	Electrical accident/ electrocution due to improper shutdown	Permit to work/shutdown and re-charging protocols not followed properly	5	10	10	500	Proper shutdown procedure should be followed under supervision of competent persons
		Non identification of circuits feeding power to different locations					Demarcation of cables through marking with separate colours,
		Improper supervision					Deployment of competent persons
		Not using PPEs					Provision and use of PPEs should be strictly followed

Table 7. Control Plan for preventing Electrical accident due to improper shutdown

Name of the Company: XXXX						
Name of the Mine: Case study underground hard rock mine						Date: 20.08.2020
Control Plan						
Hazard: Electrical accident/ electrocution due to improper shutdown						
Mechanism	**Control**	**RSP/DGC/ MG**	**Procedure**	**ERCI**	**Responsibility**	**Comments**
Permit to work/shutdown and re-charging procedures not followed properly	Judicious implementation of shutdown procedure and work permit system	Regulation 19 (CEAR 2010)	Execution of Work plan devised under MESMS, Job specific training	Med	Electrical In-charge & GVTO	Will be completed within 20th march,2021
Non identification of circuits feeding power to different locations	Proper identification of different switches and cables	Regulation 24 (CEAR 2010)	Execution of Work plan devised under MESMS, Job specific training	Low	Electrical In-charge, & GVTO	Will be completed within 20th March, 2021
Improper supervision	Deployment of authorized supervisors/ supervisors with competency certificates s	Regulation 115 (CEAR 2010)	Execution of Work plan devised under MESMS, specialized training of supervisors, Allocation as per task	Med	Electrical In-charge	Will be completed within 15th March 2021
Not using PPEs	Proper PPE should be used and ensured by Supervisor.	Regulation 19 (CEAR 2010)	Execution of Work plan devised under MESMS, Maintaining adequacy of PPE , Training and Awareness for use of PPE	Low	Electrical In-charge, Tool room In-charge and GVTO	Will be completed within 27th March 2021

5. Implementation

Safety management plan deals with accountability issues of owner, agent and manager towards miner's safety. "It's a due diligence in part of owner, agent and manager in maintaining "duty of care" requirements of OHS (Occupational Health and Safety) legislation and upon implementation is capable of reducing the impact and costs associated with work-related injury and illness" (Sinha,2016). So formal adoption of MESMS by Corporate/Mine Safety Department is a very important step towards the implementation of the designed system. In case study mine,the status of availble resoureces inform of workmen, supoervisors, testing and monitoring equipments and ample inventory for maintenance works was evaluated and necessary arrangements were made for fulfilling the specfic requirements. The next stage required effective job specific training relating control plans and Standard Operating Procedures (SOP) and explaining implementation method of MESMS. A weekly training schedule was formed to cover all emplyees of electrical deparment for class room training at Mine Vocational Training Centre(VTC). They had been provided training on various aspects of MESMS by their incharges and competent VTC instructors.Hard copies of the SOP's of various types of jobs were also provided to the participants. A list of activity wise identified hazards were also demonstrated during training and three of the major hazards viz. Electrical accident due to improper shutdown**,** Non-compliance of operating procedures and Contact with bare conductors with live electrical apparatus etc. were discussed in details. Implementation framework for executing various aspects of MESMS is shown in **Figure 02**. As per the designed framework, every applicable safety protocols and SOP concerning particular hazard were judiciously executed under the persons allocated with responsibility for the specified works **(Table 7)** and status of completion of such hazard mitigating activities within given time frame were appraised . The intricacies evolved during the system implementation were listed and various inadequacies of required compliances were also assessed. The next important stages were system deficiency management, continuous and precise monitoring, internal and external audit and fulfilling audit annotations. The designed MESMS framework had been strengthen through suitable ammendments as per the recommendations of experts, utilizers, responsible persons and audit team members during various phases of appraisal.

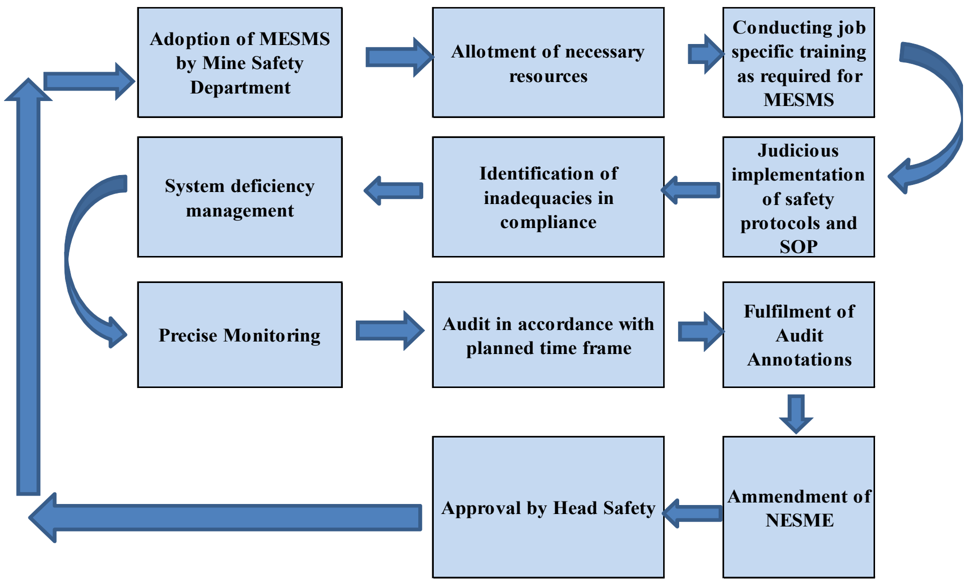


Figure 2. Implementation framework for executing various aspects of MESMS

6. Result and Discussion

The meticulous implementation the designed MESM ,2020 vemberNo from lend a hand to eliminate some of the unsafe state of affairs and unsafe acts and to integrate few positive safety practices likepersons started using appropriate PPE, obeying the aspects written in work permit system, establishing communication before shut down, filling shift end reports, religiously following pre-start inspection criteria and moreover strictly following statutory guidelines. It was observed that, the 'unsafe act' isa main cause of accident and senior electricians are very prone towards unsafe acts. The senior electricians were found fully aware of the correct method. Yet they executed improper system to save their time and hard work. It is also observed that in most cases of hazardous occurrences, the workman who carried out an unsafe act was not the victim of injury, rather it was one of his team member who had confidence on his aptitude got the injury. It indicates that the head of safety department should not emphasize only on training and development of supervisors for SOP, but it is essential that a tradesman like an electrician, operator etc. who take decision at workplace are to be paid more attention to minimize the unsafe acts. In addition to this, improper communication is also conferred as a major contributor of unforeseen incidence. It is very difficult to establish wireless communication in underground mines as the “Wireless systems did not work effectively due to complicated line of sight and signal transmission constraints” (Sarkar, Adhikari and Mangal A,2021). Thus, necessity of efficient communication system between several workplaces at underground is demonstrated as a vital constituent of MESMS.

7. Conclusion

The process of evaluating the safety performance over preceding years is a postmortem or reactive safety management effort (accident enquiry, analysis of safety statistics, finding responsible persons etc.) and is not useful in present day scenario. The healthier way would be to recognize the lead indicators like numbers and quality of training classes conducted, evaluation of worker’s risk sensitivity and understanding of MESMS etc. which can indirectly help in identifying new hazards, improving standard operating procedure(SOP), bringing existing risk control indexes(ERCI) from low to high etc. There is a need for modernizing the training system by using simulation based modules and audio visual effect oriented systems. The world of virtual reality and digital monitoring of Major hazards could be an effective step towards efficient implementation of MESMS. However, it is essential that the input of all stakeholders should be given solemn consideration during feedback management for the enrichment of such proactive approach; otherwise the process of MESMS will remain an exercise on paper and not promulgate in right way.

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Biography

Dr. Falguni Sarkar is presently working as an Assistant Professor at Department of Mining Engineering in National Institute of Technology, Rourkela (NIT Rourkela), India. He was former Head of the **'Internal Safety Organization' and 'Strata Control Cell'** for all Underground Hard Rock Mines and Open Pit Mines being operated by Uranium Corporation of India Ltd. (UCIL). His professional experiences are focused on Underground **Hard Rock Mine** Planning, designing, Scheduling and execution, Miner's Safety and health, Mine ventilation, underground water management, Monitoring environmental impact in uranium mine and underground mine communication. He has been awarded PhD. by Indian Institute of Technology (Indian School of Mines), Dhanbad, India, in October, 2017. His research is concentrated on ***"An Investigation of Multivariate Statistical Models to Estimate the Risk and Risk Perception of Mine Workers in Underground Hard Rock Mines",*** which includes Mine Safety management, Risk Assessment of different mine hazards, Behavioral Safety and Injury Epidemiology. He is a lead auditor for IS18001:2007(OHSMS) and internal auditor for ISO 14001:2004(EMS). He has knowledge in statistical modelling, Computer-Aided Mine Design and its applications.

Dr. I. Sarkar is presently working as Assistant Professor at Department of Electrical Engineering in NIT-Rourkela, India. He has been awarded PhD. on 'Cascaded H-bridge Multilevel Converter' by IIT Bombay, Powai. His industrial experience are focused on Multi-terminal Hybrid HVDC Transmission System(R&D Engineer, ABB Global Industries and Services Private Ltd., Chennai) and ITES for Energy and Utility Customers(Tata Consultancy Services Ltd., Kolkata).His areas of research interests are Multilevel Converters - its control and applications , Modular Multilevel Current Source Converter - Its control and applications , Induction Heating , Induction Motor Drive - For high power application.