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# An Efficient Electrical Safety Performance Tool for Indian Construction Industry- ESA Approach

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**Abstract**

Worker's safety in the construction industries has been strongly focussed in the recent years. Jobsite accidents have a strong impact on the construction industry. The safety record of the construction industry is very bad when compared with other industries in India. The poor safety records of the construction industries are due to several factors such as complexity of the work or system, risk nature of works, management style, safety knowledge and commitment, and personal behaviour. Construction industry in India has its own risks and challenges arising from change, which is intrinsic in construction.

**Problem**: In India fatal accident related to electrical accident contribute 12% from the data collected from the private construction industry.

**Method:** ESA approach shall be used to identify the hazards related to electrical in construction site.

**Discussion:** how to do electrical audit in the construction site with appropriate procedure with checklist in Indian construction industry. Checklist related to electrical aspect had been prepared and opportunities for research are proposed.

**Result:** ESA approach helps us to identify the electrical hazards exist, priority wise solving the problem evolving in site (electrical hazard). On implementation of ESA approach to construction site we can mitigate the electrical accident and reduce the fatal accident, lost time injuries and fire accident occurring at construction site,

**Impact on Industry:** Improvements in electrical safety in construction industry often have application in other industries.

**Keywords:** Construction industry, Electrical Safety Audit (ESA), Electrical accident, Hazard.

## Introduction

The growth and the importance of construction industries are enormous especially in the last decade. But, it is regarded as a highly dangerous industry because of the excessively high occurrence of accidents and fatalities that occur on construction sites around the world. The danger in the construction site refers to being risky, hazardous, or unsafe. Situations, tools, or other elements may be either imminently hazardous referring to an impending or immediate risk such as a bare electrical cord, or inherently dangerous such as poisons, explosives or chemicals.

Construction worldwide is a major employer of labor as huge quantities of its activities and operations have labor-intensive characteristics [1]. In Europe, for example, the construction industry employs about 7.5% of the total industrial labor force. European construction reports for 17.5% of all work-related accidents and injuries. Construction is responsible for about 22.5% of all occupational deaths, representing some 1500 fatal accidents per year [2]. For many years construction has consistently been among those industries with the highest injury and fatality rates [3].

The main cause of accidents on construction sites in various countries like United States, United Kingdom and Japan is the behavior. These hazards include injuries to workers through falling, something falling on them, and tripping over obstacles. This also applies to the developing countries like India.

Construction industry in India country has significant contribution to GDP and employs around 33 million people; hence, the issue of safety and health assumes importance. It is the second largest contributor to the GDP after the agricultural sector. It generate substantial employment and provides growth impetus to other manufacturing sector like cement, bitumen, iron and steel, chemicals, bricks, paints, tiles etc. Hence the concern for safety needs attention. The industry is characterized by the predominance of migratory and unskilled labour.

A few data in respect of the industry in India is given below

| | |
|---|---|
| Annual turnover | Rs. 3921 billion |
| Contribution to GDP | 6.2% |
| Employment | 33 million workers |
| Engineers | 4.7% |
| Technicians & Foreman | 2.5% |
| Skilled workers | 15.3% |
| Unskilled workers | 73.1% |
| Annual growth (Targeted) | 8% |

Source: CIDC Country Report 2005-2006

## Trend of Accident

As the sector in unorganized and enforcement has not yet started to its fullest extent, no accident reporting system is followed by construction companies and hence, there is no reliable and accurate accident statistics for the sector, During the period of 2003-

2005, 8 fatal and 1 major accidents were reported to the office of the chief labour commissioner central.

As per the report a survey conducted by ILO,165 per 1000 workers get injured during construction activities. In addition to that the workers are exposed to a host of hazardous substances, which have a potential to cause serious health & occupational diseases such as asbestosis, silicosis, lead poisoning etc.

## Related work

James C. Cawley [4] Electrical shock caused 99% of fatal and 62% of nonfatal electrical accidents. Comprising about 7% of the U.S. workforce, construction workers sustain 44% of electrical fatalities. Power line contact by mobile equipment occurs in many industries and should be the subject of focused research

Chia-Fen Chi*, Chong-Cheng Yang, Zheng-Lun Chen [5] study analyzed 255 electrical fatalities in the construction industry. Similar to our previous analysis of fatal falls, each electrical fatality was analyzed in terms of individual factors (age, gender, experience of the victim), task factors (performing task), environmental factors (wet area and confined space), management factors (company size measured by number of workers), source of injury, and causes for these accidents. These electrocution accidents were divided into five accident patterns: direct worker contact with an energized power line, boomed vehicle contact with an energized power line, conductive equipment contact with an energized power line, direct worker contact with energized equipment, and improperly installed or damaged equipment, to identify contributing factors for each. For each accident pattern, accident causes (failure to de-energize electrical systems, failure to maintain safe distances, improper use of personal protective equipment (PPE), poor work practice, accidental contact with exposed electrical parts, defective tools and equipment, lack of effective safety devices or unsafe environment) and prevention measures (safe work practices, insulation, guarding, grounding, and electrical protective devices) were developed based on the identified common scenarios.

From the review, it is very clear that there are very little data present on the Electrical safety on construction sites. In developing countries like India there were no research carried.

## Research Problem

Construction industry is the second largest employer after agriculture, employing over 30 million people. Agrarian background, migratory nature and a very high degree of transitory employment characterize the profile of labour in construction industry. As per the background information we could understand that there is no research has been carried out on Electrical safety in construction site in India.

General adverse physical/environmental operating conditions and the associated high-risk potential makes construction different from the other industries. These operating conditions, most of them unique to construction industry, have an influence on the safety performance.

***Temporary Nature of Work***

Construction works are generally temporary in nature. Hence most arrangements are planned and made for a short duration. This curtails application of normal safety standards and hence construction is prone to accidents. Further the feelings that the work is for short duration makes the employee to take unnecessary risks.

***Seasonal Employment of Workers***

Most of the labourers employed are agricultural workers who are unaware of industrial risks. They come to construction work only during off-season of their farming activity and return once the agriculture activity picks up. Due to this transient nature of workers, imparting safety training to them is not only difficult but also is generally ineffective.

***Time Constraint***

Quick mobilisation of men, material and resources to remote sites is a challenging task considering quality of logistical support available. Problems are many in the event heavy machinery is required to be moved over longer distances on poor road conditions. Invariably there will be delays in mobilisation of resources and subsequently the project time needs to be crashed to meet specific customer needs.

***Legal Aspects***

Till 1996, there was no specific legislation applicable to construction industry. In the absence of statutory requirement adequate attention was not given to safety at construction sites.

Chockalingam S. Sornakumar T. [6] Building and other construction workers (Regulations of Employment and Condition of Service) Act was enforced on 1st March 1996. Based on this legislation, the State and Central Governments were expected to notify rules. Central Government has also notified Central Rules in November 1998. Other states are yet to form the rules. Thus notification and enforcement of rules is still lacking.

***Major causes of Accidents***

As per a study following are the major causes, which lead to accidents at construction sites.(i.e., Statistics collected from MNC construction firm)

- Fall from height (45%).
- Fall of materials (13%).
- Electrocution (12%).
- Collapse of earth (4%).
- Run over/ hit by vehicle (10%).
- Caught in between and struck by object/ moving machinery (9%)
- Others (7%).

From the above statement it is clear that electrocution which causes 12% of accident. This paper propose ESA Approach to identify and mitigate the electrical hazard exist in the construction site.

**Proposed Methodology**

**Electrical Safety Audits (ESA) is to** Identifying potential electrical hazards to prevent or minimize loss of life and property is perceived seriously by many construction industry the world over. General safety auditing is popular where the objectives & concepts are clear whereas ESA is a specialized area that is still in the process of being understood by many.

In India, the condition is still worse. Investigations of major fire incidents in various types of occupancies over a number of years show that nearly 40% of the fires are initiated by electrical causes such as short circuits, overloading, loose electrical connections, etc.

Our experience shows that either the top management or the electrical department initiates ESAs and not the safety department. The reason could be the lack of in depth knowledge of safety officers in electrical aspects coupled with their limited involvement in electrical department's day-to-day functions.

Although electrical hazards will be identified and assessed in general safety audits, comprehensive electrical safety audits can provide a thorough review of the electrical system. This could identify potential electrical hazards, flaws in design system, maintenance system, etc.

## Elements of Electrical Safety Auditing Programme

ESA Programme can be broadly classified into 3 major areas namely:

- Pre-Audit
- Audit
- Post-Audit

The efficacy of the audit (identification & control of electrical risks) largely depends on the pre-audit and the post-audit sections. Pre and post audit elements are user / client dependent and obviously the audit depends on the audit team. Unless the ESA objectives are clearly defined and audit recommendations considered, the ESA programme will not be successful.

An effective ESA programme should include elements such as competent audit team formation, pre-audit briefing, collection & review of relevant information (preventive maintenance documentation, accident reports, electrical inspector's reports, history cards), discussion with safety & electrical officers, plant visit and then the consolidation to the top management. Finalizing the audit methodology should be in consultation with the requirements of the auditee. The ESA programme elements are discussed below.

### Pre-Electrical Safety Audit Elements

***ESA Scope of Work***

Many are still unclear about the scope of Electrical Safety audits. The terms, Electrical energy audits, Electrical engineering studies and Electrical Safety audits are interchangeably used even by many top technical officials of industries. Unless the scope of study is well understood, the objectives of the audit cannot be attained.

Defining scope of Electrical Safety audit based on the specific requirement is the first step in the process of Electrical Safety auditing.

Typical ESA scope of work could include

- Physical inspection of the plant with reference to applicable Indian standards, Indian Electricity Rules and other relevant codes of Practice & identifying electrical hazards (shocks, fires, etc.).
- Reviewing the role of electrical safety in the total safety system.
- Review of protection devices / system of the electrical installation.
- Review of adequacy of cables, motors, etc. based on actual load current measurements and cable current carrying capacities.
- Examination of adequacy of plant lightning protection system as per national and international standards to suggest recommendations as per applicable standards.
- Review of the hazardous area classification carried out in the plant as per IS: 5572 and to review the selection, installation of special electrical equipment as per IS: 5571 to suggest recommendations as per applicable standards.
- Review of electrical accidents to identify root cause of the accidents.
- Review the EPM (Electrical Preventive Maintenance) programme in the plant and to examine the documentation, checklists, work permit, test records, etc. and to suggest recommendations as per applicable standards.
- To identify training needs of the plant employees from the point of view of electrical safety.
- To evaluate the earthing system (installation and maintenance) in the plant based on IS 3043 and to suggest recommendations.
- Review of the following test records, evaluating the test results and to suggest recommendations as per applicable standards.
- Transformer oil test.
- Insulation Resistance Tests.
- Earth Resistance tests.

(The checking of test procedures and checking of test result interpretations are also part of this exercise).

- To evaluate the potential electrical fire hazards in the plant electrical installation and to suggest fire protection measures as per applicable standards and Indian Electricity Rules.
- To identify the ESD (Electro-Static Hazards in the plant and to suggest recommendations as per applicable standards.

**Note:** Generally, all the above inspections, reviews, etc. are carried out on a sampling basis.

***ESA Team Composition***

The ESA audit could be internal or external. The external ESA team should consist of

competent electrical engineers that are experienced in conducting similar types of audits. The client can ask for the resume of the ESA team members of the external agencies to make sure that they get the desired result in the areas of electrical safety by having the right people in the audit team. To ascertain the credibility of the agency, many prospective clients ask for references (where this agency has conducted ESAs for them) that can provide a better assessment of the auditing agency.

The team member should of course be familiar with all safety-related issues such as safety auditing elements, accident investigation, safety training, etc. The abilities to interpret rules, standards, etc. and to suggest practical and cost-effective safety solutions, etc. are also expected from the audit team. Effective communication skills, competency, right attitude, will to constantly update, will to share information, openness, belief in teamwork and perseverance are the other necessary qualities needed for a safety auditor. The safety audit team leader should lead the team and communicate to the client's representative in an effective manner.

***Pre-Electrical Safety Audit Questionnaire***

The details that would help the audit team (especially in case of external audit) will be included in the pre-audit questionnaire. Although the generic details will be made available to the audit agency in the initial stages, the specific details would help the team to prepare themselves to carry out the safety audit in an efficient manner. The pre-audit questionnaire for ESA could include the following aspects:

- Process details
- Electrical Single Line Diagram
- Name plate details of major electrical equipment
- Details of classified zones in the plant
- Details of flammable chemicals handled in the plant
- Details of electrical accidents in the plant
- Details of addition / expansion of the plant including electrical installation
- Overview of electrical maintenance system

***Audit Preparation / Reference***

The questionnaire is a vital tool for successful inspection and time spent on its preparation is as valuable as that taken by the audit itself. Auditing experience will reveal the need for supplementing or modifying it, provided that the auditors adopt a flexible approach to their task, and the danger of confining attention only to those matters listed in the original questionnaire must be avoided.

Checklists can be made with reference to

- Statutory Regulations
- Non-Statutory Standards (national and international)

ESA checklists could be prepared based on various applicable statutory and non-statutory standards and codes of practice. Good engineering practice found during other ES audits in similar installations can also be included in the checklists.

International standards such as API and NFPA can also referred wherever found necessary. Another important aspect in referring to various standards is the possible confusion in reconciling a safety recommendation. The factors listed below are to be considered while suggesting a recommendation, if contradicting statements are mentioned in rules / standards.

- Compliance to statutory requirement
- Safety of the people and the plant

The experience gained by the ESA team members is a very crucial factor in the compilation of audit checklists. Experienced and competent team members can offer many practical, cost-effective safety suggestions and solutions.

The checklists could contain the following sections with specific checkpoints. Grouping the observations in the following manner helps to identify and evaluate the areas of concern. Another way of categorization is having the checkpoints grouped under various plant sections / areas, which is the popular method. An advantage of this popular method is that a process section / unit in-charge can be asked to comply with the recommendations by giving a copy of the report section to him. But for the management to understand the efficacy of the various electrical safety elements, the grouping as indicated below will be of use. This way of grouping enables the consolidation exercise more effective.

***Compliance to Statutory Rules***

- Applicability of rules (Indian electricity Rules, Petroleum Rules, etc.)
- Compliance to inspector's reports
- Submission of accident intimation reports, forms, etc. in time
- Intimation of inspector before energizing new / changed electrical installation

***Electrical Shock/ Flash / Injury Hazards***

- RCCBs –selection, installation and maintenance
- Aspect of Nuisance Tripping and bypassing of RCCBs
- Bypasses fuses, MCB (Miniature Circuit Breaker), etc.
- Use of re-wirable fuses
- Earthing defects
- Use of double insulated (class II) tools, centre tapped power supply, extra-low voltage equipment for confined spaces
- Accessible live parts
- Electrical rubber mat
- Wrong identification of equipment / feeders
- Defective electrical portable tools
- Are the necessary PPEs (Personal Protective Equipments) used?
- Interlocks provided for multiple power sources?
- Is the interlocking system in place?
- Are MCC (Motor Control Centers) /PCCs (Power Control Centers) / DBs (Distribution Boards) maintained to avert flash incidents?

- Operational clearance as per Indian Electricity Rule 51
- Tripping hazards due to loose cabling/cords, etc.
- Adequacy of illumination in electrical rooms/around panels, DBs, etc.
- Stand-by power supply (Diesel Generator set)

***Electrical Fire Hazards***

- Storage of combustible materials near electrical equipment / fuse units
- RCCBs
- Master switch in warehouses
- Proper cable joint procedures as per manufacturer
- Earthing defects
- Use of non-standard fuse wires
- Bypassing of protection devices
- Deteriorated insulation
- Selection, deployment of PFEs ( (Portable Fire Extinguishers)
- Sealing of cable passes, openings, baffle walls (Passive Fire Protection)
- Tracking possibility
- Unused openings in live panels, etc.
- Possibility of ground fault / short circuit
- Mechanical protection to cables
- Loose terminations due to improper supports, crimping
- Improper gland installation, wrong lug size
- Over-rated fuses, wrongly set protection relays, etc.

***Electrical Safety Training***

- Need for electrical safety training
- Training content identification
- Periodicity
- Competency of faculty members
- Objective of training

***Earthing System***

- Installation as per approved design?
- Installation and Maintenance as per IS 3043?
- Earth resistance measured periodically?
- Test procedure
- Acceptable earth resistance values
- Is the earthing system modified when electrical installation is modified?
- Are neutral earth pits independent and separate?
- Are earth pits identified?
- Are two and distinct earth connections provided?
- Is the earth continuity tested?
- Is bonding and earthing carried out to avoid ESD hazards?

***Competency and Adequacy of Electrical Personnel***

- Competency of electrical O&M personnel
- Understanding of electrical hazards
- Are the operating and maintenance procedures amended after accidents?
- Awareness of latest electrical protection devices, hazards, etc.
- Workmanship
- Adequacy of electrical personnel
- Frequency and severity of electrical accidents
- Nature of electrical accidents
- Safety attitude

***Electrical Preventive Maintenance***

- Is there an Electrical preventive maintenance programme in place?
- Is the programme implemented? What is the slippage?
- Are the relevant standards (statutes and non-statutory) referred and incorporated in the EPM programme?
- Electrical Tests, Records, Test Procedure and periodicity (earth resistance, insulation resistance tests)
- Is the EPM programme only documented?
- Transformer tests (dielectric strength, acidity, sludge deposits, dissolved gases, etc.) and periodicity
- Periodic calibration of meters (ammeter, voltmeter, relays, temperature gauges) and test instruments (insulation resistance megger, earth resistance megger, multi-meters, etc.)

***Electrical Accident Investigation Procedure***

- Is every accident / near-miss electrical accidents investigated in detail?
- Is the root cause identified and included in the APP (Accident Prevention Programme)?
- Are the recommendations incorporated in the O&M procedures/ work permit
- Are these accident causes given importance in safety training sessions?
- Are the hazard identification techniques such as job safety analysis, Fault Tree Analysis, etc. utilized?

***Importance of Electrical Safety in the Overall Safety System***

- Periodicity of comprehensive ESAs
- Understanding of electrical hazards
- Electrical checkpoints in the safety checklist
- Electrical safety items the in safety committee agenda
- Implementation priority for electrical hazards
- Electrical Work Permit System
- Electrical Operating Procedures
- Electrical hazard identification techniques used (Electrical HAZOP, Electrical Job safety analysis, etc.)

***Lightning Protection***

- Is the Lightning protection system as per IS 2309?
- Are the numbers of down conductors direct and adequate?
- Are all the structures and building under the zone of protection?
- While reviewing lightning protection, are both the plan and elevation of structures, etc. considered?
- ESP (Electronic system Protection) for electronic system / equipment
- Is the earthing for the electrical and lightning systems interconnected?
- Are the storage tanks / chimneys and other special structures protected?
- Earth electrodes- maintenance / periodic tests / acceptable value
- Awareness of basic concepts of lightning such as types of lightning, predictability factor, protection concepts, etc.

***Hazardous Area Classification and Installation of Special Electrical Equipment***

- Are hazardous areas classified as per IS 5572?
- Are the special electrical equipments selected and installed as per IS 5571?
- Are the electrical equipments maintained as per IS 2148 and IS 13346?
- Review of area classification in case of process change / plant modification, etc.
- Approval of area classification drawings as per statutory rules
- Maintenance of flame-proof equipments
- Use of ordinary electrical equipment in hazardous areas
- Awareness of O&M personnel about hazardous area and flame-proof equipments

***Electro-Static (ES) Hazards and Control***

- Are the ES hazards identified in the plant?
- Are the non-conductive parts where ES hazards are identified, bonded & earthed?
- Is the concept of equi-potential bonding and ES hazards clear to O&M personnel?
- Does the tanker (carrying flammable chemicals) de-canting procedure, switch-loading, etc. defined and made clear to all concerned?

***Electrical Protection System***

- Are the protection relays in place and set in the main PCC / MCC?
- Are the relays set in accordance with calculated, design parameters in mind?
- Are they calibrated and tested periodically?
- Availability of HRC fuses, standard fuse wires, MCBs, MCCBs, RCCBs, etc.
- Are the transformer protection devices in place? (Bucholtz Relay, Oil Temperature Relay, Winding Temperature relay, Silica Gel Breather, Explosion Vent, etc.)

***Electrical Single Line Diagram / Lay Out Diagram / Equipment Layout / Electrical Control diagram***

- Unauthorized Temporary Installations?
- Updated?
- SLD reflects the actual installation?
- Duly approved by statutory authorities?

As part of safety auditing, for that matter, in any auditing, cross-checking helps to ascertain facts although auditing is not a policing activity. For instance, checking of the status of actual equipment maintenance against documented maintenance checklist, say, earthing of a motor. In documented checklist, it may be marked as 'in order' but on actual verification, earthing may be missing. Our experience in carrying out ESAs prove that generally, maintenance checklists are compiled and filed for the sake of satisfying either ISO certification or statutory / audit requirements and that actual implementation is seldom religiously carried out.

Audits are carried out on a sampling basis. Although large sampling helps to get a more realistic view of the safety aspects in the plant, this may not be practically possible due to various factors such as time, etc. However, if the client so desires, the sampling percentage can be clearly defined and communicated to the auditing agency. Generally in ESAs, the main areas are sub-station, main power transformer, distribution transformers, PCC room, One or two MCCs, Lighting panel, a few DBs, critical motors, etc. are inspected. Obviously, the sampling depends on the size of the plant electrical system, criticality / hazardous nature of plant process, etc. The areas that need focused study will have to be looked into in depth. The aspects that need focused study could be frequent electrical accidents in an area/plant, electrical panel flash incidents, major statutory non-compliance, etc.

**Pre-Audit Meeting**

Single point coordination is recommended from both the sides of the audit agency & the client. The person should be well aware of the entire electrical installation and preferably a senior electrical engineer. He should have good rapport with all departments and should be communicated with all departments to get the required information. The areas to be visited and activities to be inspected should be agreed with the members of the management concerned before the auditing begins. It is a normal practice to brief the client's officers in the opening meeting the audit scope, methodology, etc. The client should also be informed about the possible assistance the ESA team might require such as:

- Permission to photograph electrical hazards to highlight the situation
- Assistance of an electrician to carry out various measurements / tests (load current, insulation resistance, earth resistance) including the test instruments as necessary
- Access to relevant test reports /records/inspection records/maintenance documentation/accident investigation reports/work permits/training records, etc.
- Permission to isolate section of the electrical system or equipment as necessary without affecting production

**Electrical Safety Auditing**

**Field Visit**

The field /plant visit is the most important part of the ESA programme. This involves visiting the plant to identify electrical hazards as per the scope of the audit. In electrical safety audits, the incoming electrical supply receiving section (outdoor substation and main transformer) is inspected first. Then the main sub-station housing the PCCs or MCCs and the cable gallery (if present) is inspected. Next are the electrical equipments installed in various process sections, the cabling and the distribution transformers located in the plant are visited. The aspects such as earthing, lightning protection, maintenance condition, loose cabling, temporary wiring, electrical fire hazards, shock potential, etc. are critically looked-into. The checklist provided in the 'Pre-audit Preparation' section is rather a comprehensive attempt, covering almost all-electrical safety aspects.

The verification of the actual installation against available drawing (such as electrical single line diagram, earthing lay out, etc.) is also carried out during the field visit.

**Discussion with Safety and Electrical personnel**

Clarification / discussion is carried out with the plant officials (electrical /safety) during the field visit. A senior electrical engineer and preferably, safety officer should also be part of the external electrical safety audit team. This is a continuous activity right from the beginning of the audit. Clarifications help to ascertain facts and to understand the system in a better manner. The on-site interactions will help to clear many doubts and to suggest many practical solutions to the client.

**Review of Documentation / Records**

Normally, this part is taken-up after the field visits. All the relevant maintenance documentation, test records, electrical records, electrical inspector reports, OEM (Original Equipment Manufacturer) service manuals, History cards are subjected to detailed examination. All the relevant drawings (electrical single line diagram, earthing layout, hazardous area classification drawings, protection system schematic, equipment layout, lightning protection drawings) are also checked against actual installation and commended upon, with reference to applicable standards.

**Post-ESA Elements**

***Report Format***

There is no standard ESA report format available. Considering aspects such as clarity of report, usefulness to the client, and to streamline the report, the following format is recommended(**Table:1**).

**Table 1:** ESA Report Format.

| Sl. No. | Observed Electrical Hazard / Unsafe Condition /Non-Compliance | Implication | Recommendation | Implementation Priority |
|---|---|---|---|---|
| | | | | |

The implication column helps the user to appreciate the hazard, to understand the potential and to prioritize the implementation based on its severity. The report format (Table: 2) where the observations and recommendations are written together (non-tabular format) is popular and is the one that is commonly in use nowadays. The tabular report format helps to streamline the report, by shedding the unnecessary written matter, making the report crisp and focused.

The implementation priority helps the management to take appropriate action in an organized manner.

**Table 2:** Severity Table.

| Sl. No. | Electrical Risks | Severity | Consequence | Implementation Priority |
|---|---|---|---|---|
| 1. | -Statutory non-compliance<br>-Fatal shock hazards<br>Sustained fault condition due to defective earthing<br>Fire / explosion due to improper electrical equipment selection / maintenance in flammable atmospheres<br>-Fires / Explosion due to electrostatic dissipation in flammable atmospheres | -High Risk<br>- Hazards that pose immediate threat to life & property | -Fatal /catastrophic<br>-Penalty from statutory authorities | Priority A<br>Immediate correction |
| 2. | -Defects in protection system<br>-Maintenance flaws that could lead to equipment failure /fire / flash<br>-Operational problems due to poor illumination wrong identification, inadequate clearance, etc.<br>-Deterioration of equipment insulation / earthing condition due to lack of monitoring /testing | -Medium Risk | -Critical | -Priority B<br>-Corrective action in the next available opportunity |
| 3. | -Hazards that pose no immediate threat to life and property<br>-Lack of implementation of maintenance programme due to inadequate personnel | Low Risk | Marginal | - Priority C<br>Corrective action in a phased manner recommended<br>-Long-term corrective measure |

Total involvement and commitment of the top management is absolutely essential for the success of any safety audit programme right from the audit initiation stage. They have to demonstrate the active support to the safety management system by providing the required resources, be it manpower or materials. The top management has to instruct all the relevant employees to take part in the safety audit and to provide all necessary help to make the auditing successful. The management system is fundamental to loss prevention. Many prudent management are experiencing the obvious benefits from the concept of STEP - Safety Through Employee Participation which is very crucial for the success of any safety programme.

## Conclusion

A properly designed, planned and executed electrical safety audit programme can bring out many hazards that could save life & property. An auditor is expected to help the auditee to identify the potential electrical hazards, to make the auditee understand the consequences and also to help them through the process of implementation of Electrical Safety recommendations.

Safety audits are an important part of a company's control system. The auditing scheme does not remove from the management and supervisors the necessity for regular checking and rechecking to ensure that people under their control are working in a safe manner. Their application and use do not remove the need for proper care and responsibility at all levels in day-to-day operations. ESA approach will be useful for construction industry to mitigate the accident occurring at site. As some one has rightly said, 'Safety is good business & like most business situations, has an optimal level of activity beyond which are diminishing returns'. If adequate initial expenses are made on safety, site will be inherently safe from major accidents.

## Reference

[1] Coble, R. and Haupt, T.C. Safety Coordination and Quality in Construction, Proceedings of International Conference of CIB Working Commission 99 and Task Group 36, Milan, Italy, 22-23 June, pp. 159- 164, 1999.

[2] Berger, J., "Safety Coordination and Quality in Construction", Proceedings of International Conference of CIB Working Commission 99 and Task Group 36, Milan, Italy, 22-23 June, pp. 51-60, 2000.

[3] Hanna, A.S., Isidore, L.J. and Kammel, D. "Implementation of Safety and Health on Construction Sites", Proceedings of the First International Conference of CIB Working Commission W99, Lisbon, Portugal, 4-7 September, pp. 145-156, 1996.

[4] James C. Cawley*, Gerald T. Homce., "Occupational electrical injuries in the United States, 1992–1998,and recommendations for safety research, Journal of Safety Research ,pp 241– 248, 2003.

[5] Chia-Fen Chi*, Chong-Cheng Yang, Zheng-Lun Chen," In-depth accident analysis of electrical fatalities in the construction industry", International Journal of Industrial Ergonomics, PP 635–644,2009

[6] Chockalingam.S,Dr.T.Sornakumar," Organising for HSE in construction of industrial project", International journal of research, analysis and evaluation, March 2010

[7] Hasher Pallathu Kadavil, James Palmer," Electrical hazards: causes and prevention", Anaesthesia & Intensive Care Medicine, Pages 458-460,November 2010.

[8] Mark Tooley," Electrical hazards: their causes and prevention", Anaesthesia & Intensive Care Medicine, Pages 366-368, November 2004

[9] Frank Guldenmund, Andrew Hale, Louis Goossens, Jeroen Betten, Nijs Jan Duijm," The development of an audit technique to assess the quality of safety barrier management", Journal of Hazardous Materials, Pages 234-241,March 2006.

[10] John C. Birkmire, James R. Lay, Mona C. McMahon," Keys to effective third-party process safety audits ",Journal of Hazardous Materials, Pages 574-581, April 2007.

[11] G. Grote, C. Künzler," Diagnosis of safety culture in safety management audits ", Safety Science, Pages 131-150,February 2000.

[12] Dong Zhao, Jason Lucas, Walid Thabet," Using Virtual Environments to Support Electrical Safety Awareness In Construction", IEEE Proceedings of the 2009 Winter Simulation Conference, 2009.