ELECTRICAL SAFETY AUDITING –APPROACH & METHODOLOGY

Why Electrical Safety Audits (ESA)?

Identifying potential electrical hazards to prevent or minimize loss of life and property is perceived seriously by many chemical industries 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 factories, around 8% of all fatalities are due to accidents caused by electricity. Data compiled by international organizations like Fire Protection Association (FPA), UK and the National Fire Protection Association (NFPA), USA indicate that nearly one fourth of all fires are caused by electrical appliances or installations. 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:

1. **Pre-Audit**

2. **Audit**

3. **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. Safety bodies like OISD recommends audits by internal team as well as external teams. 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 IER 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 EPM 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 ESD 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 focussed study will have to be looked into in depth. The aspects that need focussed 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

II. 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.

III. 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.

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 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 focussed.

The implementation priority helps the management to take appropriate action in an organized manner. Several clients specifically requested LPA to recommend implementation priority of the recommendation.

Implementation Priority Ranking

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

ESA Report Contents

- ***Management Abstract***

The management abstract as the name implies contains the salient observations noted during the audit and the recommendations in a nutshell. The top management is a busy lot and generally appreciates when matters are presented in a crisp and focussed manner, highlighting the most critical aspects. They will be eager to understand those hazards that are harmful to their employees and to the property. Any prudent management will consider seriously potential hazards that can affect their business (directly as well as indirectly) and will take immediate action. Considering the importance of this section, every care has to be taken in choosing appropriate words and to effectively convey the message, depending upon the criticality of the hazard.

- **Introduction**

This section generally contains the ESA scope of work, exclusions in the audit scope, assistance provided during the audit, details of the audit team, client's officials contacted during the audit, audit methodology, and the audit duration. This section can also contain summary of the client's safety system, safety auditing policy, training strategy, Accident Prevention Programme, and the management commitment towards safety. The details of client's business interests and other specific details of the plant process also could form part of this section.

- **Overview of Electrical System**

The overview section contains the details of the electrical power supply and the power distribution. This section can also discuss the details of critical electrical installations, name plate details of critical electrical equipment, recent alterations/additions carried in the electrical installation, captive generation details, etc. This section can also discuss about the future expansion plans with respect to electrical capacity.

- **Specific Observations and Recommendations**

This is the most important section containing the specific observations and recommendations in the plant observed during the audit. Normally, the observations are noted area/plant wise. Checklist method is found effective and various standards (both statutes and non-statutes) are available for reference. The format for this section is given in this paper.

- **Lightning Protection System Evaluation**

The review of the existing lightning protection system of the plant as per the applicable national (IS: 2309) and international standards (NFPA 780) is carried out in this section on a sample basis. The various maintenance aspects are also evaluated in this section. If required, the fundamental step of ascertaining the need for protecting buildings /structures by calculating the risk factor is also carried out. The experience the audit team gained while auditing other similar plants /installations are also discussed in the report for the benefit of the client.

- **Electro-Static Hazards- Control Measures**

ESD (Electro-Static Discharges) is a critical area where the potential ESD hazards are to be identified and necessary solutions are to be provided. Making the client aware of the potential accidents that can occur due to Electro-static discharges, minimum ignition energy required for fire /explosion, concept of equi-potential bonding and earthing, etc. are also crucial to make them understand the ESD hazards in the right

light. Many plants handling flammable chemicals do not understand the concepts of ESD and hence do not follow de-canting procedure that is very unsafe. The reference standards used for identifying and controlling electro-static hazards are IS:7389 and NFPA 77.

- **Hazardous Areas – Observations and Recommendations**

This is another crucial area that needs to be evaluated critically. Although hazardous areas are critical, they are mostly neglected in most of the hazardous plants. The design principle of flameproof equipment makes it a special equipment that needs 'special care'. Area classification into zones and installing various types of electrical equipment are the critical factors in controlling accidents in hazardous areas. Once the hazardous areas are classified and the right electrical equipments are installed, the onus of maintaining these special electrical equipments becomes the duty of the electrical maintenance personnel. In almost 90 % of the cases, the maintenance of these electrical equipments is not up to the required level.

The hazardous area classification is carried out by process experts depending upon the possibility of existence of flammable vapour/gases as per IS:5572 /OISD 113 /API RP 500. The selection of electrical equipments is carried out as per IS:5571 and is to be maintained as per IS:13346 and IS:2148 provides the details of special features of flameproof equipments.

- **Review of Electrical Accidents and Control Measures**

The electrical accident record in the plant is analyzed in this section. Discussions are also carried out with electrical and safety officers to fully understand the accident and to pinpoint the root cause. The accidents report format as well as the root cause identification methods are analyzed and recommendations are provided.

- **Review of Fire Hazards and Fire Protection Measures for Electrical Installations**

This section covers the identified potential electrical fire hazards, fire prevention methods and the fire protection strategies to be adopted by the client. The suitable fire detection (LHS –Linear Heat Sensing cable, smoke/fire detectors) and extinguishing medium (fixe as well as portable) are also recommended depending upon the application. The focus areas will be the electrical installation / equipment where potential of fire hazards are relatively high such as MCC/PCC rooms, transformers, power plants, DG rooms, cable galleries, warehouses, store rooms, office buildings, etc.

- **Electrical Maintenance Review**

The electrical maintenance aspects in toto will be reviewed in this section. The standards followed competency of O&M personnel, tests carried out as part of maintenance, etc. will be reviewed in detail. Implementation slippage, test value interpretation, appropriateness of action taken, etc. will also be evaluated. Various national standards (partial list provided in this paper) are used for this purpose.

- **Review of Electrical Test Records and Test Procedures**

Tests that are carried on sample basis are evaluated in this section. Tests are carried out when it is felt that the values recorded are not credible. Normally, the following tests are carried out.

1. Insulation resistance values of select cables / motors
2. Load current measurements of feeders/motors
3. Earth resistance tests

The test procedures that are adopted in the plant are also verified against national standards. OSD standards as well as national standards provide valuable guidance regarding acceptable values. The load currents measured are checked against the current carrying capacity of cable/motor after applying applicable rating/de-rating factors to identify overload condition.

- **Annexures (for reference, guidelines, etc.)**

This section consists of various published reference materials that could be beneficial to the client in the area of electrical safety. The plant electrical single line diagram and the key electrical equipment lay out diagram may also be attached in this section for future ready reference.

- **Photographs (to highlight electrical hazards)**

This is an important section, which is used to highlight electrical hazards identified in the plant. The permission to photograph plant sections is taken in the pre-audit meeting. Generally, auditing agencies maintain confidentiality of the safety audit report as well as the photographs.

Once the photograph is attached in the report with the relevant caption, management appreciates the hazard in a better manner than when it is expressed in text form.

Management Briefing

The management briefing at the end of safety auditing is another crucial factor in the effectiveness of auditing because it is the top management who needs to be convinced about the consequences of Electrical hazards. For effective management briefing, the auditor should possess a combination of effective communication skill, thorough understanding of the hazards and the capability to offer safe & cost-effective solution. Audits may also result in questions needing policy decisions and proposals for capital expenditure. It is therefore important that the board and the senior management are seen to be the authority for the formal audit system and have committed resources- manpower and money- to implement the changes agreed. It is also essential that a senior management representative is directly involved in the review of the audit report leading to an action plan and in subsequent formal reviews of progress on the plan.

Consolidation of the audit is the most important part of the ESA programme. If the management is not convinced of the seriousness /consequence of the hazard, the safety recommendation will not be implemented. Competent officer (preferably, the ESA team leader) with effective communication skills is ideal. Consolidation also includes grouping the micro observations into macro level categorization. Macro aspects could be classified into 5 major areas:

1. **Design Flaws**

- Inadequate protection.
- No / updated Electrical Single Line Diagram.
- Inappropriate hazardous area classification / selection of electrical equipment.
- Improper lightning protection.
- Electrostatic Hazards.
- Inadequate Earthing.
- Selection of non-standard cables/ motors / transformers.
- No passive fire protection in cable passes.

2. **Electrical Maintenance Aspects**
   - Non-standard maintenance practices.
   - Only documentation available to comply with ISO requirement.
   - No periodic tests on earthing system, transformer oil, insulation resistance tests, etc.
   - No periodic calibration of protection relays/ test & measuring instruments.
   - Bypassing of RCCBs (Residual Current Circuit Breakers).
   - Ordinary copper wires used instead of HRC (High Rupturing Capacity) fuses.
   - Openings in feeders/ distribution boards.
   - Lack of identification marks on DBs (Distribution Boards), junction boxes.
   - Poor maintenance of flameproof equipment.

3. **Training Intervention**
   - Lack of basic understanding of electrical hazards.
   - Repeated (high frequency, low severity) electrical accidents.
   - Electrical accidents are not investigated in detail.

4. **Defects in Systems & Procedures**
   - Bypassing of electrical work permit procedure.
   - Wrong tanker (carrying flammable liquids) decanting procedure (ESD hazards).
   - Bypassing of the interlocking system for multiple power sources.

5. **Management Commitment**
   - Employing non-competent persons/ wrong attitude of employees.
   - Non-compliance to statutory regulations.
   - Electrical safety not prioritized in the overall safety system.
   - Believes that 'Nothing happened to us till now, so nothing is going to happen to us'.
   - Electrical accidents are not investigated in detail and are considered inevitable.
   - Electrical safety is perceived as too technical to be handled by safety department and hence considered to be separate. No interference of safety department in electrical activities.

Duration of Electrical Safety Audits

The duration of ESA depends on the size of the plant /building. Normally, the pre-audit meeting, understanding the process and electrical distribution takes almost 2 hours and a quick round in a small plant will take another 2-3 hours totaling to a half day. The initial plant visit helps the audit team to identify areas of concern, which will be evaluated in detail during the field visit. Field visit, discussion with electrical O&M, safety officers will take almost 80% of the audit time and is the most important element of the ESA programme. Reviewing the records, maintenance documents, etc. will consume approximately 10% of the audit time. Pre-Audit meeting, the initial quick plant visit, photography, and briefing management will take the rest 10% of the total auditing time. The time required for report preparation is certainly time consuming and depends of the quantum of work.

Interim Report

Since the final report will take some time for preparation, an interim report containing the salient observations noted in the audit and the recommendations is sent to the client within a period of 15 days. This will enable the client's top management to take action on most critical safety problems without delay.

Confidentiality of Report

Generally, the safety audit agencies maintain confidentiality of the report.

Follow-up audit

A monitoring system is required to ensure that recommendations are communicated and understood that the required work, or changes, is implemented. Methods for achieving this within the allotted time scale vary but will include direct reports to senior management or to appropriate works/ projects technical committees. This could be an agenda in the safety committee meetings.

Updated Electrical Safety Information Transfer through ESAs

Temperature Detection and electrical accident Control

Many safety conscious organizations are using non-contact type, laser guided thermometers to detect temperature rise in electrical panels, equipments, etc. This hotspot detection tool if used effectively can increase reliability by identifying potential problem areas in advance without initiating a shutdown. The concept of the use of thermometer is based on the principle that 'generally, electrical failures are preceded by abnormal heat build-up'. Thermometers can be used for diagnostic and preventive inspection of electrical equipment.

US study showed that 26% total electrical failures are due to loose connections and poor terminations. Indian scenario as per an expert cannot be less than 50%. Immediate effect will be overheating of joints and terminations due to increased contact resistance.

Hotspots can form due to:

- Use of improper lugs / incomplete crimp
- Poor contact
- Bolts carrying current
- Dirty contact surface
- Extra Joints
- Cut wire strands to accommodate smaller lug
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High temperatures (or hotspots) could indicate:

- High contact resistance
- Loose/ tight connections
- Unequal loading
- Over loading

Although this versatile temperature-measuring instrument is used in many plants, it is observed that the proper interpretation and action taken on temperatures exceeding normal values requires improvement. A few tips for temperature value interpretation, extracted from a manufacturer's application guide are given below for guidance.

1. 30 degree centigrade + ambient indicates a serious fault condition and needs investigation.
2. Temperature difference between phases – 5 degree centigrade or more- a potential problem.

The temperature detection at electrical connections, etc. becomes very crucial considering the fact that the effect of temperature on insulation life will reduce by 50% if the maximum temperature is exceeded by 10 degree centigrade.

Protection from Electrical Arc Fires

Recently, an innovative electrical safety device called AFCI (Arc Fault Current Interrupter), designed to prevent electrical fires caused by arcing in low voltage circuits has been developed in America. After the invention of GFCI (Ground Fault Current interrupter) /RCCB (Residual Current Circuit Breaker) forty years back, AFCIs are considered the first major advance in electrical protection. It is reported that the American government has made it compulsory to install AFCIs in all new American homes by 2002.

Fires in electrical wiring break out at wire/cable joints, end terminations, etc. because of mechanical damage to insulation, overloading, insulation deterioration, etc. result in high temperature build-up resulting in fires. Arcing generates high intensity heat and expels burning particles that can easily ignite combustible materials. Acing faults are supposed to have the potential of initiating fires.

A few of the typical conditions where arc faults may start include:

- Damaged wires
- Worn electrical insulation
- Loose electrical connections
- Overheated or stressed electrical cords and wires

AFCIs are designed to detect the arcing patterns of serial and parallel or arcs to earth and to trip the circuit. It is envisaged that this electrical safety device with its unique 'arc detection circuitry' would considerably control electrical fire accidents.

SUMMARY

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.

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 schemes 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.

An organisation instituting safety audits must define the objectives and scope of the audit, its frequency, the elements it should contain and the methods to be used.

An organisation's culture determines the number and severity of accidents, how they are handled and the number and magnitude of accidents. Japan's accidents seven times lesser than those in the US because of the difference in 'culture climate' in the two countries. It is natural that the philosophy of the top management cascades downs through the organization and reflects on every aspect of its functions. Accepting accidents, as part of doing business is mismanagement A pragmatic approach works better than a dogmatic one.

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, plants will be inherently safe from major accidents. To conclude, the management system is fundamental to loss prevention and hence, Safety & Loss Prevention programme in an organization stand or fall by the attitude of the top management.