EXTERNAL AUDITS TO EVALUATE AND ENHANCE ELECTRICAL SAFETY AND MAINTENANCE

Paper No. ESW2014-42

C. Satish
Life Senior Member, IEEE
10-5-3/2/6 Masab Tank
Hyderabad
AP 500028
India
c.satish@ieee.org

Daryld Ray Crow.
Life Senior Member, IEEE
DRC Consulting Ltd.
336 36th Street #389
Bellingham, WA 98225
USA
draycrow@ieee.org

Abstract - The performance of electrical systems depends on, among other things, the type and quality of maintenance and the safe operation of the equipment. It is necessary to evaluate the quality of the maintenance and safety procedures utilized within the safe work practice program. The paper advises the use of external auditing of electrical systems and maintenance programs for the advantages it brings to the company. The paper also explores the concept of a possible mandatory certification of "conformance to safe standards" by a neutral party.
Various standards, recommended practices and statutory codes used in different countries are listed in this paper. The paper critically examines these publications and possible shortcomings. Development of a globally valid standard for electrical safety which integrates the best of the various standards is hypothesized and championed here. The paper recommends combining the various electrical standards into a holistic version of a global electrical safety standard for use in your maintenance and electrical safe work practice policies and procedures.

Index Terms — Electrical Safety Audits, Global Safety Standards, Conformance Certification, Lock out and Tag out, Electrical Inspection Checklists.

I. INTRODUCTION

The objective of any industrial power system is to provide a safe, reliable system at the lowest cost. Achieving this depends on proper 1) design, installation, initial verification and commissioning tests, and 2) correct operation and maintenance procedures plus a formal electrical safety program. The importance of a formal electrical safety program is seldom fully appreciated for its true value. An electrical safety and maintenance program is necessary for the continued safety of personnel and reliability of the plant. There is a need to evaluate these qualities closely. The problem at present seems to be:

- What should be the right standard /recommended practice to be used ?
- Who should evaluate the implementation?
- Should safety audits be conducted?
- Should audits be completed by a neutral third party or completed internally?
- Should there be a safety conformance certification?
- Should these conformance certifications be mandatory?

The objective of the authors in presenting this paper for engineers and managers in charge of electrical facilities and systems in heavy industrial facilities is for them to consider the need, the issues, and possible solutions to attaining an evaluation of an electrical safe work practice and quality maintenance program.

II. PRESENT SCENARIO

A sound electrical safety and maintenance program is built by adopting a combination of elements in various standards, recommended practices, regulations and other publications into one blended, cohesive and comprehensive document. Additionally, for companies with a presence in more than one country, the document can become more complex in order to cover all regulatory requirements in each country.

Different countries follow different sets of publications in developing effective programs.

North American standards are:

- NFPA 70E-2012, National Fire Protection Association, *Standard for Electrical Safety in the Workplace*
- NFPA 70B-2013, *Recommended Practice for Electrical Equipment Maintenance, Workplace Electrical Safety Standard*

- CSA Z462 - Canadian Standards Association, *Workplace Electrical safety*
- OSHA 29 Occupational Health and Safety Administration - *Code of Federal Regulations (CFR) Subpart R 1910.269 Subparts S 1910.331-335*
- ANSI Z10-2005, Occupational Health and Safety Management Systems
- NETA MTS-2007 International Electrical Testing Association – *Maintenance, Testing, Specifications for Electrical Power Distribution Equipment and Systems*
- IEEE Std 3007.2 -2010, *Recommended Practice for Electrical Maintenance of Industrial and Commercial Power Systems*
- IEEE Std 3007.3-2012, *Recommended Practice for the electrical safety of Industrial and Commercial Power Systems*
- IEEE Std 625-2001, *Recommended Practice to Improve Electrical Maintenance and Safety in the Cement Industry*

European standards are:

- OHSAS 18001-2007 *Occupational Safety and Health Management System Requirements*
- EN 50110-1 – 2005 - *Operation of Electrical Installations*
- IEC 60079-17, 2007, *Electrical Installations, Inspection and Maintenance of Electrical Installations in Hazardous Areas*
- IEC Standard 504-2009, IECEx *Scheme for Certification of Personal Competencies for Explosive Atmospheres*
- UK's *Electricity at Work Regulations*, 1989

India's Standards are:

- India's Central Electricity Authority (CEA) *Electrical Safety Regulations* 2010
- India's Oil Industry Safety Directorate (OISD) Standards
- Indian Standard IS 5216, *Guide for Safety Procedures and Practices in Electrical Work*

Australia's Standard is:

- Safe Work Australia – Code of Practice - *Managing Electrical Risks in the Workplace*

The above is a set of reference documents for consideration when compiling or updating your company's electrical safety and maintenance program.

An excellent review of the features of NFPA 70E as compared to the EN 50110-1 written by G. Parise, P E Sutherland and W J Moylan gives an understanding of the differences within similar standards between two countries trying to achieve the same basic objective.[1].

In the US, ANSI developed electrical testing standards that are followed by the vast majority of US companies.

Compliance with OSHA 29 Code of Federal Regulations (CFR) 1910 Subparts R and S is mandatory in the USA. To make sure of this compliance, one needs to refer to NFPA 70 E and IEEE Standard 3007.3 for recommendations, guidance and implementation.

Of the European standards, EN 50110-1 is applicable to work involved for electrical installations while IEC 60079-17 is specific to equipment in hazardous areas. IEC Standard 504-2009 is limited to persons working in hazardous locations.

UK's *Electricity at Work Regulations* 1989 and India's CEA *Electrical Safety Regulations* 2010 are both statutory and compliance is mandatory. Both however need reference to many other British and Indian Standards. India's CEA *Electrical Safety Regulations* state that every factory management shall designate a qualified electrical engineer with experience as 'electrical safety engineer. The designated engineer will ensure the observance of the CEA Regulations and inspect, test and keep records of inspection and tests and make them available to government Electrical Inspector.

NFPA 70B, NETA Maintenance Testing Specifications and IEC 60079-17, IEEE Std 3007.2 and IEEE Std 625 deal with maintenance planning and give detailed technical guidance on the various maintenance tests.

OHSAS 18001 Standard and the ANSI Z10 are safety management system standards and do not cover specific details of electrical safety. As Landis Floyd indicated [2], these standards cover three control measures of safety management, namely elimination of the hazard, substitution of less hazardous equipment/materials and engineering controls to reduce exposure or severity of electrical hazards. These three measures are not covered in depth within NFPA 70E or EN 50110-1

An examination of the above standards shows some of the potential weaknesses within each set of documents as the sole source of a safety and maintenance program. It also highlights the advantage of increasing the scope of your electrical safety and maintenance program to include a more universal approach by utilizing the key strengths within each document.

III. Electrical Safety and Maintenance Program

Achieving safety in operation and maintenance requires the establishment and implementation of a comprehensive electrical safety and maintenance program. IEEE Standard 3007.3 gives the structure for a safety and maintenance program. Typical elements of an electrical safety and maintenance program are also given in NFPA 70E and other Standards. These may

include:

- Hazard Awareness
- Safe Work Practices, Procedures and Controls
- Hazard Identification and Risk Assessment
- Qualifications of Personnel and Training
- Electrical Safety Auditing
- Test Instruments and Equipment
- Inspections and Testing
- Lock Out/Tag Out Procedures
- Limits of Approach to live parts
- Personal Protective Equipment
- Use of Temporary Safety Grounds

The Regulations and Standards mentioned above stipulate that only "qualified personnel" are permitted to do electrical system operation and electrical equipment maintenance work above 50 volts. They must also be given training periodically to impart knowledge of the systems and equipment, craft skills, awareness of the hazards and of personal protection, necessary job planning and briefing, ability to distinguish energized electrical conductors and circuit parts to determine their voltage, and knowledge of the safe distances and clearances for various voltages and situations.

The Indian CEA *Electrical Safety Regulations* specify the syllabus for training of persons authorized to operate and maintain power stations and substations of 100 MW and 132 KV and above respectively. It is equally important to add the training syllabus for persons authorized for working in industry also. The IECEx *Scheme for Certification of Personal Competencies for Explosive Atmospheres* [3] is a comprehensive document listing the description of the necessary competencies of persons. However it is limited to work in hazardous areas.

Detailed methods of checking and testing the insulation, earthing system integrity, arc-flash hazard and overload and earth fault protection are given in NFPA 70B, IEEE Std 3007.2, India's OISD Std 137 and NETA Maintenance Testing Specifications.

UK's *Electricity at Work Regulations* stress the importance of insulation, earthing, Residual Circuit Devices and equipotential bonding for prevention of shocks and arc flashes. Protection against shock and arc flash by using Residual Current Devices and Ground Fault Circuit Interrupters are detailed in many standards. NFPA 70E includes tables for determining distances to be maintained against possible shock.

Permit processes and lockout/tagout procedures are described in many standards in detail, for example, in NFPA 70E, OSHA 29 CFR and OISD Standard 137. Implementation of a Lockout/tagout policy is critical as the majority of shock and burn injuries are due to incomplete deenergization and unexpected energization of lines, cables, or machines. As Mark Scott and Andrew Segers indicated, the main causes for the above type of injuries are: "failure to lock out before work and failure to test before touching" [4].

The five basic and essential steps to be taken before work is permitted to start are listed in EN 50110-1 as

1. Disconnect completely
2. Secure against re-connection
3. Verify that the installation is de-energized
4. Carry out earthing of all parts on which work is to be carried out
5. Provide protection against adjacent exposed energized electrical conductors and circuit parts

Note: Only point 4 in the above list is mentioned in Rule 19 of India's CEA *Electrical Safety Regulations*.

US and European Standards describe the choice of Arc Rated clothing, Personal Protective Equipment, and insulated tools. The selection, specifications, and testing of arc-rated clothing, rubber insulating equipment, insulated tools, and other PPE are given in these Standards.

NFPA 70E and EN 50110-1 provide details for the limits of approach boundaries to exposed energized electrical conductors and circuit parts and the requirements to enter each boundary. OSHA 29 CFR 1910.269 and 1910-331-335 prescribe safety rules for training, lockout/tagout, PPE, working on or near live parts and overhead lines. According to surveys conducted in the USA from 1992 to 2009, 43% of all electrical fatalities involved overhead power line contact. The second largest cause was contact with wiring and electrical equipment [5].

Inspection checklists are convenient and very helpful for ensuring nothing is missed in safety and maintenance and especially for self-assessment and audits. Some examples of checklists exist in IEC 60079-17, India's CEA *Electrical Safety Regulations* (Schedule IV), and India's Oil Industry Safety Directorate's OISD Standard 145 '*Guidelines on Internal Safety* Audits, Procedures and Checklists'. None of these are comprehensive enough. It is necessary to develop more comprehensive checklists to cover the continued exercise of safety and maintenance while the plant is in production. Checklists are included in NFPA's *"Electrical Inspection Manual with Checklists"* [6], which is limited to the initial verification of compliance with the US National Electric Code. The periodic safety and maintenance audits include some of the checks, which are performed at the time of commissioning the plant. The checklists listed in the NFPA *Electrical Inspection Manual* are also of use for periodic audits during the entire life of the plant. In addition a comprehensive checklist based approach for equipment isolation and switching is developed by Shahid Jamil and John D Aeiker [7].

An electrical safety and maintenance program should preferably be global instead of each country following a different set of standards. Consideration should be given to creating a globally valid audit and conformance certification and an evaluation of the quality of safety and maintenance across various countries. Electrical injuries are caused by reasons which are the same in the US, India or any other country. An electrical shock does not depend on nationality. There is much in common in various national standards in the basic aspects of electrical safety and maintenance. Hence it is logical to say that a global electrical safety and maintenance program is feasible and desirable. The program should be clear and easy to implement and maintain.

IV Auditing

Safety and maintenance performance & conformance with regulations and standards can be assessed systematically and periodically by safety audits. An audit is a verification of the implementation and conformance of the electrical safety and maintenance programs and regulations. The assessment should be objective, without trying to blame people. The objective is to improve the safety and maintenance performance, not to punish employees. These audits are more detailed and rigorous compared to statutory inspections. Companies which perform periodic audits have fewer incidents than those that do not include auditing as a requirement in their safety program. Effective safety audits will improve safety in your facility by:

- Recording present conditions
- Helping location management identify strengths and weaknesses
- Checking compliance with mandatory regulations and codes
- Monitoring equipment integrity
- Promoting improvements in electrical safety work practices
- Documenting performance improvements

Regulations in the US require safety audits not to exceed once every three years. The audit requirements in some India standards require audits not to exceed once every 5 years. Industries in the oil and gas sector in India are required to do internal safety audits every year and safety audits by an outside group not to exceed every 2 years. The members of the outside team are appointed by the ministry of petroleum and chemical's Oil Industry Safety Directorate.

Apart from the limited statutory inspections mandated by bodies like OSHA and government inspectors, there are two types of audits. One is by self-assessment and the other is by an external auditor. Most companies are not adopting safety and maintenance audits by external auditors. The limitations of internal audits are obvious. One should not audit one's own work. R.L. Hudleston and Ray Crow showed the benefits of a third party audit [8]. External auditors may also not have fear of retaliation from local management. An audit by a third party can discover things that self-assessors might overlook. Some of the most obvious reasons for the use of external auditors are:

1. They generally have sound working knowledge and experience about the industry they are reviewing and can offer relevant and timely suggestions for improvement that make good business sense.

2. They often have no previous opinion as to whether or not they should point out errors or not. They just do. There is no boss to please or keep happy about their results and they are free to be objective.

3. Best practices can be shared through auditors as they have been in similar settings and also settings which are not the same and can offer information about how other businesses may have solved the same type problems effectively.

To be effective, the audit has to be performed by experts. Auditors should be knowledgeable, credible, objective, and trained. In addition auditors must know the workplace, the system being audited, the previous accident history and the company's policies and operating and maintenance procedures. Auditors should be trained to identify hidden or potential hazards. An effective audit should include criterion and protocols for each issue being audited. It is desirable to have a rigorous certification or competence program for external safety auditors. In India such certification is mandatory for energy auditors and financial auditors apart from these audits being mandatory. In fact, safety audits by certified external auditors also need to be made mandatory.

A few years ago one of the authors of this paper received a request from a cement plant in India to help with aligning the electrical system with IEEE 625–2001. This request included helping the company receive IEEE's accreditation/certification for conforming to IEEE 625. The cement company has ISO 9001 and ISO[1] OHSAS 18001 certification. The author discussed the feasibility of IEEE accreditation and issues involved with a few experts in PCIC and IEEE Standards. While it was agreed by some that the idea is interesting and has

merit, it was clarified that IEEE presently has no system of granting accreditation to companies that conform to any IEEE standard.

The following points were raised in the discussion about accreditation/certification for conforming to IEEE standards: IEEE ISTO has a Conformity Assessment Program ICAP that appears to be primarily for products and technologies and so far does not include safe work practices and maintenance issues. In the field of safety/maintenance the standards are related to recommended practices and guides which are suggestive in nature. It is easier to develop conformance programs for standards which use" shall " and "must". However ISO OSHAS 18001, IEC ExCoP 504 Standard, and International Safety Rating Systems are all concerned with certification/conformance to "practices". Implementation of ISO OHSAS 18001 Standard and IEC ExCoP Standard 504 involve a rigorous certification process unlike ANSI Z10 and NFPA 70E. IEEE has sufficient standards to evaluate if plant practices conform to its standards, recommended practices, and guides. The next issue to address is integration of these safety and maintenance standards, recommended practices and/or guides of America, Europe etc and make their application and accreditation universal. It is recommended that a paper be presented in a conference to canvas the ideas and elicit the response of the attendees. In the Indian petroleum industry the focus is on getting the rating of International Safety Rating System (ISRS) and not on ISO OSHAS 18001. ISRS measures an organization's effectiveness in safety management by independent auditing and giving an overall rating out of a maximum of 10.

V. CONCLUSIONS

There is a need to evaluate the quality of electrical safety and maintenance integrity. It is preferable to have this evaluation created by a competent and certified external auditor and possibly making it mandatory. There are many standards and recommended practices and/or guides apart from mandatory codes worldwide, which will be required to be used in this process. It is better to integrate them into as few in number as possible and adopt them universally in the future.

As for formal accreditation to the standards in safety and maintenance processes, it has to be driven by the commercial value to user industries, advantage to IEEE and inspectors. Even though accreditation may be the ultimate goal, a first step is 1) to find out if there is a value of accreditation within various groups, and 2) to develop a document of procedure outlining guidelines for evaluation. This document can extract or give references to existing standards and recommended practices and be supplemented with some new information where needed.

The objective of the authors in presenting this paper is to seek the views and feedback from those working in or for industry on the various issues raised in this paper.

VI. REFERENCES

[1] G. Parise, P E Sutherland and W J Moylan, "Electrical Safety for employee workplace in Europe and in USA", IEEE Trans on Industry Applications, pp 1091-1098, July / August 2005

[2] H Landis Floyd, "Safety Management Systems", IEEE Industry Applications Magazine, pp 19-24, May/June 2011

[3] M. Cole and K.McManama, " IECEX Certification of Personnel Competencies ", IEEE Industry Applications Magazine pp 27-48 Jan/ Feb 2013

[4] Mark A Scott and Andrew Segers, " A Global Safety Program ", IEEE Applications Magazine, pp 27-33, May/June 2013

[5] James C Cawly and Brett C Brenner, Analyzing On-the-job Electrical Injuries", IEEE Industry Applications Magazine, pp 16-20, May/ June 2013

[6] Jeffery S Sargeant and Noel Williams, " Electrical Inspection Manual with Checklists", NFPA 1999

[7] Shahid Jamil and John Aeiker, "Electrical Equipment Isolation", IEEE Industry Applications Magazine, pp 44-50, May/ June 2011

[8] R L Huddleston and D R Crow, "A Second Set of Eyes-The benefits of a Third Party Audit", PCIC Annual Conference 2002

VII VITA

Satish Chaparala (M'74, LSM'05) graduated from Osmania University, India in 1965 with a Bachelor's degree in Electrical Engineering and then obtained a Master's degree from JNT University, India in 1977 in Industrial Engineering. His retirement in 2002 as Manager Electrical followed after 30 years of working in Indian Drugs and Pharmaceuticals Limited. He was the founder Chairman of the IEEE IAS / PES Joint Chapter at Hyderabad, India. He organized 4 IAS workshops by 4 Chapters in India on Electrical safety. He has coauthored a PCIC award winning paper in IAS Annual conference in 2000. Satish received 1) PCIC Electrical Safety Excellence Award in 2002, 2) IEEE EAB Meritorious Achievement Award in Continuing

Education in 2002 and 3) 2005 IAS Distinguished Service Award :

Daryld Ray Crow (S'68, M'72, SM'03, LSM'07) graduated from the University of Houston in 1969 with a BSEE degree. After graduation Ray went to work for the Aluminum Company of America where he provided engineering support for Alcoa plants worldwide on the design, installation, and operation of power and rectifier systems, provided plant engineering support which included electrical safety, served as team leader for writing a number of Alcoa electrical standards including the development of and training for Alcoa's electrical safe work practice standard. He retired from Alcoa in 1996. After retiring from Alcoa, Ray worked for Fluor Global Services and Duke Energy as a Principal Technical Specialist providing design and consulting electrical engineering for plant power distribution systems and safe work practice programs, standards, and assessments/audits.

Ray presently is the Principal Technical Specialist and owner of DRC Consulting Ltd. and performs consulting work on electrical safe work practices standards, assessments/audits, electrical safe work practice training, and electrical engineering projects.

He was chair of the Petroleum and Chemical Industry (PCIC) Safety Subcommittee 2004-2006, chair of the 2004 IEEE IAS Electrical Safety Workshop, is an alternate member on the NFPA 70E technical committee "Standard for Electrical Safety in the Workplace", a member of the IEEE 1584 Committee, and was the working group vice chair for the 2007 revisions to IEEE 463 "Standard for Electrical Safety Practices in Electrolytic Cell Line Working Zones".

Ray has co-authored and presented papers and tutorials on electrical safety and auditing for the PCIC and has presented safety topics and tutorials at the IEEE Industry Applications Society Electrical Safety Workshops and IEEE IAS Pulp and Paper Industry Conference. In 2010 Ray received the IEEE IAS Petroleum and Chemical Industry Committee Electrical Safety Excellence award.