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Electrical Safety Risk Management

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Introduction

With all of the knowledge, standards, and regulations concerning electrical safety procedures and hazard assessments in today's industry, risk management should be a priority not an option. This paper addresses the decision-making techniques needed to make sound electrical safety decisions using established industry standards and regulations; understanding electrical hazards; understanding the shock and arc flash hazard analysis; and the electrical safety and risk assessment (audit) process.

Managing risk means that the electrical hazards must first be identified, through assessments and analysis, and then prioritized in order to minimize, monitor, and control the probability and impact of unfortunate incidents and events that may occur.

Developing an effective electrical safety risk management plan is a critical part of any project or business. Unfortunately, this process is often overlooked or avoided due to inadequate knowledge of the electrical hazards and the requirements for electrical safety analysis, programs, procedures, and training. If everything goes smoothly and without incident that approach works great, however, issues do arise, incidents do occur, and without a well developed plan, even small issues can become emergencies or catastrophic events. In this paper we will look at risk management and assessments from the standpoint of planning for adverse events or incidents.

Risk is the positive or negative effect of an incident. It is determined by the probability of an incident occurring along with the impact on employees, and electrical equipment and systems. There are several factors that must be considered in analyzing risk, including, but not limited to the following:

- What could happen?
- What is the probability of the incident happening?
- If the incident occurs what is the impact?
- What can be done to mitigate the problem(s) or potential incidents?
- What can be done to reduce the impact should the incident occur?
- How much exposure is there to employees and/or property?

OSHA 1910.132(d)(1) requires the employer to "assess the workplace to determine if hazards are present or are likely to be present," which is essentially identifying where the assumed risks exist and what must be considered as part of Risk Management plan.

Established Industry Regulations and Standards

The principal legal requirements for electrical safety are developed and issued by the Occupational Safety and Health Administration (OSHA), of the U.S. Department of Labor, which started with the OSHA Act being signed into law on December 29, 1970. OSHA has provided the industry with several performance-oriented regulations that address the minimum requirements for safe work practices that are necessary to protect employees from the electrical hazards. These regulations include:

- 29 CFR 1910. 303-.308, Design Safety Standards for Electrical Systems
- 29 CFR 1910.331-.335, Electrical Safety-Related Work Practices
- 29 CFR 1910.147, Control of Hazardous Energy Source (Lockout/Tagout)
- 29 CFR 1910.269, Electrical Power Generation, Transmission, and Distribution
- 29 CFR 1910, Subpart I, Personal Protective Equipment (PPE)
- 29 CFR 1910.146, Permit Required Confined Spaces

This paper will reference several of these OSHA regulations and requirements along with a corresponding electrical safety consensus standard published by the National Fire Protection Association (NFPA). The NFPA 70E, *Standard for Electrical Safety in the Workplace*, that reinforces the OSHA requirements, will be referenced. Compliance with these regulations, along with the NFPA 70E standard, will help provide protection to employees who work with exposed energized conductors and circuit parts of electric equipment by providing the requirements for various hazards analysis and safe work practice procedures, along with the required personal protective equipment (PPE). Compliance will also help reduce the number of electrical injuries and fatalities that result from using unsafe equipment and work practices by employees. These regulations and standards, along with an understanding of the electrical hazards and the electrical hazard analysis process, lay the foundation for the electrical safety risk management plan.

Understanding Electrical Hazards

Having a good understanding of the electrical hazards is crucial to electrical safety risk management. It would be almost impossible to determine the risk or manage something that is not understood. This section will provide some statistical information as well as a brief explanation of the hazards of electricity.

Statistics show that several hundred deaths occur annually as a result of electrical shock. Over one-half of these deaths are the result of contact with low-voltage, primarily 120-volts. Many of the electrical shock accidents that occur in commercial and industrial facilities are the result of contact with 277-volts. This is due to the extensive use of 277-volt fluorescent lighting. The National Institute for Occupational Safety and Health (NIOSH) statistics show that electrical contact results in 4,000 non-disabling and 3,600 disabling injuries annually, plus ONE death in the workplace every day in the United States alone. Other studies show that 10-15 employees are hospitalized every day with electrical arc flash related burns.

Surprisingly, over half of those killed in electrical accidents are not in tradition electrical fields but are from fields such as contractors, outside service personnel, painters, laborers, and drivers. [Detailed surveillance data and investigative reports of fatal incidents involving workers who contacted energized electrical conductors or equipment are derived from the National Traumatic Occupational Fatalities surveillance system maintained by the National Institute for Occupational Safety and Health (NIOSH)]. The U.S. Bureau of Labor Statistics also provides information on non-fatal electrical incidents for electrical shock and burns for various industries (Figure 1).

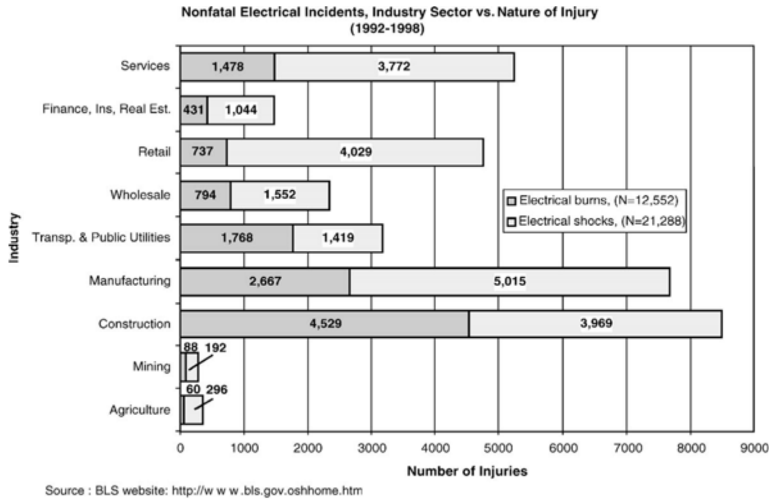

Figure 1. This chart identifies the number of nonfatal electrical incidents in various industry sectors. (Courtesy of the Bureau of Labor Statistics)

Electrical Shock

Electrical shock occurs when a person's body completes the current path between two energized conductors of an electrical circuit or between an energized conductor and a grounded surface or object. Essentially, when there is a difference in potential from one part of the body to another current will flow. The effects of an electrical shock can vary from a slight tingle to immediate cardiac arrest. The severity depends on several factors:

- Body resistance (wet or dry skin are major factors of resistance)
- Circuit voltage (voltage as low as 50 volts to ground)
- Amount of current flowing through the body (determined by the body resistance and system voltage)
- Current path through the body (will the current pass through a vital organ)
- Area of contact
- Duration of contact

It takes a very low value of current, flowing through the human body, to cause death or serious physical harm. There have been many studies performed in this area with different values of current causing each effect. The following table illustrates average values of current and the effects as compiled and averaged from several published studies (Table 1):

The "Shock Hazard Analysis" required by NFPA 70E provides the guidance needed to determine the level of shock hazard. This analysis also determines the shock protection boundaries, the approach limits for qualified and unqualified employees, and the required PPE.

Current	Effect
1 mA	Barely perceptible
1-3 mA	Perception threshold (most cases)
3-9 mA	Painful sensations
9-25 mA	Muscular contractions (can't let go)
25-60 mA	Respiratory paralysis (may be fatal)
60 mA or more	Ventricular fibrillation (probably fatal)
4 A or more	Heart paralysis (fatal)
5 A or more	Tissue burning (fatal if vital organ)

Table 1. This table represents average values of current and the effects on the human body compiled primarily from OSHA and Ralph Lee's papers on this subject.

Electrical Arc Flash

Various studies, on the causes of electrical injuries, show that a large number of serious electrical injuries involve burns from electrical arcs. There are actually three different issues with the arc flash hazard; the arc temperature or flash-flame, the incident energy (radiant), and the pressure developed by the arc (blast). The main concern with the arc temperature is the flash-flame and ignition of clothing.

The amount of energy will determine the temperature of the arc, which can reach a temperature of 20,000^{0}K (Kelvin) or about 35,540^{0}F. Some studies report temperatures as high as 34,000^{0}K (about 60,740^{0}F). At approximately 203^{0}F (96^{0}C) for one-tenth of a second (6 cycles), the skin is rendered incurable or in other words a third-degree burn. The incident energy threshold for the onset of a second degree burn is 1.2 cal/cm^2 and the onset of a third degree burn is 10.7 cal/cm^2.

As can be seen by this, it does not take a very high temperature or very much incident energy to cause severe injury, which may result in extreme pain and discomfort or death to the worker. The American Burn Association provides statistics concerning the survivability of electrical burns, based on the age of the worker and the percentage of body burn (Figure 2).

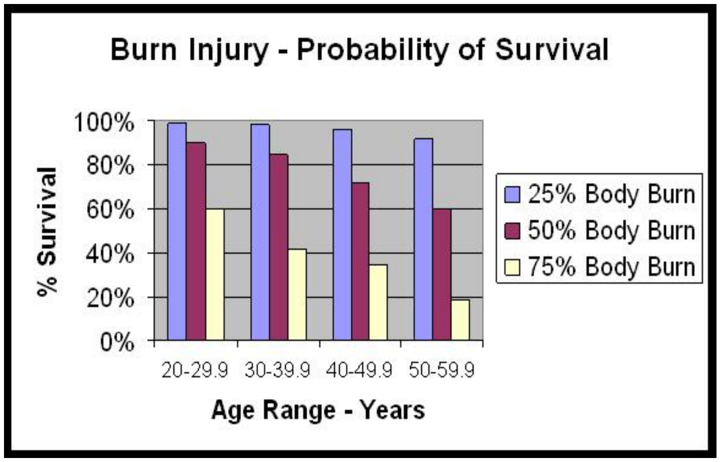

Figure 2. This chart provides statistics concerning the survivability of electrical burns based on the age of the worker and the percentage of body burn. (Courtesy of the American Burn Association)

The "Arc Flash Hazard Analysis" required by NFPA 70E, is used to determine the incident energy of an electrical arc flash, establish the arc flash protection boundary, and identify required PPE. This standard also requires that an arc flash hazard analysis be performed "in order to protect personnel from the possibility of being injured by an arc flash."

The best way to avoid this hazard is to stay away from energized electrical equipment, especially when disconnecting devices are being operated. Electrical equipment rooms should never be used for storage, break rooms, offices, shops, or anything else other than the electrical equipment. If a failure of the equipment occurred and the room was occupied, injuries or fatalities could occur.

Electrical Arc Blast

The third major hazard of electricity is the rapid expansion of the air caused by an electrical arc. This occurrence is referred to as an electrical arc blast or explosion. According to studies on the subject, the pressures from an arc are developed from two sources; 1) the expansion of the metal in boiling and vaporizing, and 2) the heating of the air by passage of the arc through it. As an example, copper expands by a factor of 67,000 times when it vaporizes. As a result one $inch^3$ of copper vaporizes into 1.44 $yards^3$ of vapor. OSHA states: "The pressures developed by high-energy arcs can damage equipment causing fragmented metal to fly in all directions. In atmospheres which contain explosive gases or vapors or combustible dusts, even low-energy arcs can cause violent explosions."

Ralph Lee's paper, entitled "Pressures Developed by Arcs" (IEEE 1987), discusses methods that can be used to determine the amount of damage that a short circuit can cause in switchgear and the buildings where the switchgear is located.

Understanding Electrical Hazards Analysis

This section of the paper addresses the requirements and considerations used to perform the "Shock Hazard Analysis" and the "Arc Flash Hazard Analysis" in order to determine the voltage exposure and the arc flash energy which are necessary in order to select the proper PPE. The

Electrical Hazard Analysis is used to determine the Limited, Restricted, and Prohibited Approach Boundaries as well as the Arc Flash Protection Boundary. Below are the definitions of these terms as found in NFPA 70E-2009, Article 100:

Boundary, Limited Approach

"An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists." NOTE: Limited Approach Boundary may be more or less than Arc Flash Protection Boundary as illustrated in Figure 3.

Boundary, Restricted Approach

"An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased risk of shock, due to electrical arc over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part." (Figure 3)

Boundary, Prohibited Approach

"An approach limit at a distance from an exposed energized electrical conductor or circuit part within which work is considered the same as making contact with the electrical conductor or circuit part." (Figure 3)

Boundary, Arc Flash Protection

"When an arc flash hazard exists, an approach limit at a distance from a prospective arc source within which a person could receive a second degree burn if an electrical arc flash were to occur." NOTE: The Arc Flash Protection Boundary may be more or less than Limited Approach Boundary as illustrated in Figure 3.

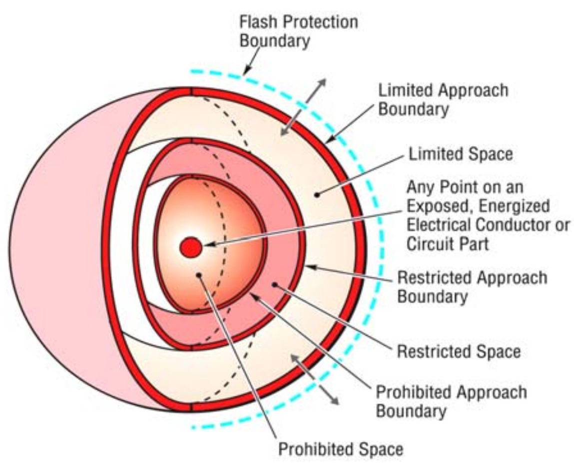

Figure 3. This figure provides an illustration of the four electrical hazard boundaries defined above.

NFPA 70E-2009 states that if circuits, operating at 50 volts or more, are not deenergized (placed in an electrically safe work condition) then other electrical safety-related work practices must be used. These work practices must protect the employee from an arc flash, as well as inadvertent contact with live parts operating at 50 volts or more. Each analysis must be performed before an employee approaches exposed energized electrical conductors or circuit parts, within the Limited Approach Boundary. NFPA 70E-2009, paragraph 130.2(B) FPN provides a reminder that the Flash Protection Boundary may be a greater distance from the exposed energized parts than the Limited Approach Boundary, in some instances.

An overview is provided of the principle types of electrical hazards analysis, along with a discussion of the relevant standards and regulations pertaining to the subject.

Shock Hazard Analysis

This analysis will: determine the voltage that a person would be exposed to, establish the shock protection boundaries, and identify the personal protective equipment requirements. The analysis should examine the most common causes of injuries and fatalities from the following contributing factors:

- Contacting overhead power lines;
- Faulty insulation;
- Improper grounding;
- Loose connections;
- Defective parts;
- Ground faults in equipment;
- Unguarded live parts;
- Failure to deenergize electrical equipment when it is being repaired or inspected;
- Intentional use of obviously defective and unsafe tools; or
- Use of tools or equipment too close to energized parts.

These factors form the foundation of the shock hazard analysis.

Arc Flash Hazard Analysis

The principle factors used in the determination of the arc flash hazard to personnel are:

- Available short-circuit current at the arc location.
- Duration of the electrical arc.
- Distance from the arc to personnel.
- The arc gap.
- Environmental conditions and surroundings at the arc location.

To accurately assess the arc flash hazard, and make appropriate decisions regarding arc rated personal protective clothing and equipment, it is necessary to fully understand the operation of the system under fault conditions. The assessment must also include matching the appropriate clothing and equipment for the arc flash hazard, which would include, but not be limited to; arc rated flame resistant (FR) clothing, safety glasses or goggles and face shield, balaclava, and/or flash suit with hood. This requires both a short-circuit analysis, in all likelihood down to the panel board level, and a protective device coordination study. It is a common misconception that arc flash hazards are an effect of only high voltage. The actual arc flash hazard is based on available short-circuit current and protective device clearing time, not available voltage. In certain conditions, a low voltage arc's duration is longer than a high voltage arc. With this information available, the magnitude of the arc hazard at each work location can be calculated using several techniques. These techniques include:

- NFPA 70E-2009, Standard for Electrical Safety in the Workplace
- IEEE 1584-2002, IEEE Guide for Performing Arc-Flash Hazard Calculations

Each of these techniques requires an understanding of anticipated fault conditions, and the limitation of the calculation method, both of which are beyond the scope of this paper.

The results of the Arc Flash Hazard Analysis are most useful when it is expressed in terms of the incident energy received by exposed personnel. Incident energy is commonly expressed in terms of calories per centimeter squared (cal/ cm^2). Arc flash protective clothing is rated in terms of its Arc Thermal Performance Value (ATPV), and expressed in cal/cm^2.

Blast Hazard Analysis

An electrical blast, or explosion as it is often termed, is the result of the heating effects of electrical current and the ensuing arc. This phenomenon occurs in nature as the thunder that accompanies lightning, a natural form of an electrical arc. Unfortunately, little can be done to mitigate the blast hazard, at least in terms of personal protective clothing or equipment. A major mitigation technique would be to reduce the available short-circuit current by installing current-limiting devices, such as current limiting reactors or using current limiting fuses.

Blast pressure calculations can be used to determine whether enclosures will withstand an internal fault if sufficient manufacturer's data is available. It may be more important to merely recognize the magnitude of the hazard so that appropriate safety practices, such as correct body positioning, can be incorporated into work procedures.

During an electrical arc, both the conducting material and the surrounding air are heated to extremely high temperatures. The resulting expansion of the air and vaporized conductive material creates a concussive wave surrounding the arc. The pressures in this wave may reach several hundred lbs/ft^2, destroying equipment enclosures and throwing debris great distances. The pressure created during an electrical arc blast is directly proportional to the available short-circuit current at the arc location. With an up-to-date short-circuit study available, the anticipated arc blast pressure can be estimated from tables or charts.

Electrical Safety and Risk Assessment (Audit) Process

The foundation for conducting the hazard risk assessment or audit must be established first. The OSHA Act referenced earlier, states "An Act - To assure safe and healthful working conditions for working men and women…" Section 5(a)(1) of the OSHA Act, commonly known as the "General Duty Clause," states that "Each Employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees." OSHA 29 CFR 1910.132(d) further states "The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of personal protective equipment (PPE)." To assist in accomplishing this, the employer should implement self-assessment or inspection programs to ensure that the electrical systems and equipment are properly designed, installed, operated, and maintained in a safe and reliable condition.

Electrical safety inspections should also be conducted to verify full compliance with OSHA 29 CFR 1910 Subpart S along with applicable portions of 1910.269, 1910.147, and 1910.146, as well as industry consensus standards such as NFPA 70, *National Electrical Code*; NFPA 70E, *Standard for Electrical Safety in the Workplace*; NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance;* and where applicable ANSI/IEEE C2, *National Electrical Safety Code*. Compliance with these regulations and standards will help to ensure that employers are maintaining electrical systems and equipment in a reliable and safe working condition, as well as each employee’s utilization of safe work practices and appropriate electrical protective equipment. Inspections also assist supervisors and managers in meeting electrical safety goals set by the company for regulatory compliance.

These inspection programs should be carried out by a knowledgeable, qualified person in order to identify deficiencies in electrical equipment or systems and to correct or properly document any deficiencies found. One way to ensure that the inspection program is on target is to have electrically qualified company safety personnel conduct the inspections, or another option is to hire a contracted third party electrical safety inspector. Using a person from outside the facility will often lead to discovery of items and deficiencies that may be overlooked by self-inspecting. The written electrical safety inspection program should be reviewed on a periodic basis, by qualified persons to ensure that the check-lists are current and are being utilized. Inspections should include a review of the entire electrical safety program and safe work practice procedures for energized and deenergized electrical work. Written work practices, personal protective equipment, and electrical equipment and systems should be inspected periodically for compliance with current standards and regulations. Inspections should also include “work in progress” to ensure that each worker understands and is implementing the safe work practices and procedures.

A major component of the risk assessment (audit) is a root cause analysis of the deficiencies identified during the inspection. Changes or corrections in processes, practices, and procedures should be analyzed to help prevent a reoccurrence. Any items identified in the inspection or lessons learned should be communicated to others in the organization that may benefit from the information.

Audit (Inspection) Guidelines

Employers should perform a self-assessment or inspection to determine the adequacy of their written electrical safety program and procedures, including electrical protective equipment, and to ensure that they are being implemented. It should also include an inspection of the facility electrical systems and equipment to ensure compliance with the installation and maintenance regulations and standards.

There are numerous subjects and items that should be addressed in an electrical safety inspection. The list below identifies several typical deficiencies that are commonly found during electrical inspections:

- Lack of or incomplete operating one-line diagrams
- Inadequately trained and qualified operators and maintenance technicians
- Incomplete inadequate deenergized work procedures
- Inadequate or nonexistent electrical safety program
- Inadequate or nonexistent energized safe work procedures
- Loose, broken, or disconnected grounding and bonding conductors
- Corrosion in electrical equipment
- Incomplete inadequate preventive maintenance practices and procedures
- Exposed energized conductors and circuit parts – covers left off or doors left open, not properly latched or bolts/screws missing
- Unused openings not effectively closed
- Working space around electrical equipment, 600-volts or less not provided and maintained

- Working space around electrical equipment, over 600-volts not provided and maintained
- Lack of proper identification of disconnecting means
- Improper or unapproved extension cords
- Damaged extension cords
- Damaged cord- and plug-connected equipment
- Ground-fault circuit interrupters not tested per the listing and labeling of the device
- Ground-fault circuit interrupters not being used where required for temporary wiring
- Availability and condition of electrical PPE

The above list does not include all deficiencies identified during electrical inspections, but it represents commonly noted deficiencies. Most types of industries and facilities will include a list similar to this, plus they may include other deficiencies not identified here. The point is that facilities must be inspected by an electrically qualified person in order to identify all of the electrical deficiencies and to develop a plan to correct and/or eliminate these deficiencies in order to protect employees and to provide reliable and safe electrical equipment and systems. In order to reduce and manage risk these types of inspections must be done on an ongoing basis. Inspections cannot be a one-time event when it comes to electrical safety.

Analyzing Risk

As mentioned earlier, risk is the positive or negative effect of an incident. It is determined by the probability of an incident occurring along with the impact on employees and electrical systems. The following factors must be considered in analyzing risk, including, but not limited to:

What could happen?

Before this question is answered, an important factor must be addressed. Employees must be qualified and understand how the equipment functions under normal and abnormal conditions. By possessing this knowledge the employer and employee can better predict the risk concerning what could happen if electrical equipment or systems fail.

What could happen if electrical equipment is not properly maintained? There is an increased risk of equipment failure if regularly scheduled maintenance is not performed. Most lubricants, used with circuit breaker operating mechanisms, will become sticky or harden within three to five years on average, which would very likely cause a delay in the operating time of the circuit breaker. This time delay will increase the incident energy of an arc flash, should a short circuit occur, exposing employees to an increased danger.

Another factor that must be addressed is the use of uninsulated hand tools. When uninsulated tools are used on or around energized electrical conductors and circuit parts, the risks of short circuits or ground faults are increased. If a screwdriver slips off a terminal and goes to ground, a ground fault will be created. If a tool is dropped into the equipment it could contact the energized bus or terminations and cause a phase-to-phase or phase-to-ground fault which in turn creates an arc flash and blast incident.

What is the probability of an electrical incident happening?

The probability of equipment failure increases if the electrical equipment and systems are not properly maintained. If maintenance is not performed, in accordance with the manufacturer's instructions and consensus standards, equipment failure is likely to happen. A good example of this is found in IEEE std. 493, IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (the Gold Book); Chapter 5, Preventive Maintenance; Section 5.2 Relationship of maintenance practice and equipment failure; Table 5-2 – Percentage of failure caused from inadequate maintenance vs. month since maintained, left column - Failure (months since maintained), More than 24 months ago, states that circuit breakers have a 77.8% failure rate. What this means is that the circuit breaker will not operate within the manufacturer's specifications. If the circuit breaker cannot open in the specified time there will very likely be an increase in incident energy, should an electrical arc occur. The note following Table 5-2 states: "From the IEEE data obtained, it was possible to calculate "failure rate multipliers" for transformers, circuit breakers, and motors based upon "maintenance quality." These failure rate multipliers are shown in Table 5-3 and can be used to adjust the equipment failure rates shown in Chapter 10. "Perfect" maintenance quality has zero failures caused by inadequate maintenance." Maintenance of circuit protective devices, protective relays and circuit breakers, is a vital part of risk management.

When the available short circuit current in an electrical system is greater than the interrupting rating of the equipment there is an increased risk of total equipment failure if a fault occurs. If the current is higher than the rating of the equipment and a short circuit occurs the equipment will likely sustain damage, sometimes so extensively that the equipment ruptures and the pressures throw debris several feet often with enough force to injure or kill anyone standing near the equipment.

Another probable cause of electrical incidents, primarily due to short circuits and ground faults, is the use of unsulated hand tools.

The environment in which the electrical equipment is installed can also increase the probability of an incident occurring. Heavy dust, along with high humidity and condensation, increases the arc flash risk factor. This condition coupled with improperly assembled or deteriorated splices and terminations can be the breeding grounds for tracking, which will eventually fail, often time creating violent explosions in the equipment.

If an electrical incident occurs what is the impact?

The impact of an incident with electrical equipment can range from an inconvenience with interrupting power to a single piece of equipment to the shutting down of the entire facility. Unfortunately there are far too many cases when the incident results in injury to an employee(s) or worst case a fatality.

What can be done to mitigate the problem(s) or potential incidents?

Mitigation starts with performing an electrical hazard analysis and conducting electrical inspections to identify the electrical hazards, deficiencies in electrical equipment and systems, and to identify the required safe work practices and personal protective equipment. Developing an electrical safety program and procedures and enforcing compliance is a major step in mitigating the impact of an incident on employees. Regularly scheduled maintenance of electrical equipment is vital to mitigating the possibility of an incident occurring. In addition to the equipment maintenance, employees must be trained and qualified to perform the required maintenance, safely and efficiently. Another mitigation technique, that must be used, is a complete lockout/tagout program that will establish an electrically safe work condition. The electrical lockout/tagout program must be in compliance with the applicable sections of OSHA 29 CFR 1910.147, 1910.269, and 1910.331-.335, along with NFPA 70E, Article 120.

As mentioned earlier, a major arc blast mitigation technique would be to reduce the available short-circuit current by installing current-limiting devices, such as current-limiting reactors or using current-limiting fuses.

What can be done to reduce the impact should an electrical incident occur?

Reducing the impact of an incident should include, but not be limited to, the following: employees must be trained and qualified; equipment must be properly maintained; the employer must perform an electrical hazard analysis and inspections in order to identify and quantify the electrical hazards in their facility, including the shock hazard analysis and the arc flash hazard analysis; the employer must provide written electrical safety programs and procedures, and enforce compliance; the employer must provide all required personal protective equipment; short-circuit analysis and protective device coordination studies must be completed and kept up to date; and one-line electrical drawings must be available and kept up to date.

How much exposure is there to employees and/or property?

Exposure will always be there because electricians, technicians, and operators will have to interface with electrical equipment as part of their everyday activities. Circuit breakers are operated, opened and closed, as part of daily operations. Circuit breakers are racked out and in whenever electrical lockout/tagout is performed. The risk of an incident is always there when there is a human/equipment interaction. Performing a job/task analysis to determine what work activities employees will do, along with the electrical hazard analysis, will help determine any exposure to the hazards and their potential impact on employees and equipment. Establishing an effective electrical safety program, and enforcing compliance, will help ensure that employees will not be exposed to electrical hazards unless they are properly protected.

Managements Role

Managing risk means that the electrical hazards must be identified, through assessments and analysis, and then prioritized in order to minimize, monitor, and control the probability and impact of unfortunate incidents and events that may occur.

Management ultimately bears the burden of effectively administering the electrical safety programs. Their involvement in the development and implementation of an electrical safety inspection program is vital to the success of the overall electrical safety program. There are several areas that must be considered when developing the inspection program; they include, but are not limited to: hazard assessments; inspections of equipment, systems, procedures, training records; safety and health training; and evaluation of the existing safety and health management system.

To assist employers in developing effective safety and health management systems, OSHA published recommended *Safety and Health Program Management Guidelines* (*Federal Register*

54(16): 3904-3916, January 26, 1989). These voluntary guidelines can be applied to all places of employment covered by OSHA.

These guidelines identify four general elements that are critical to the development of a successful safety and health management system. These are the following:

- Management leadership and employee involvement,
- Worksite analysis,
- Hazard prevention and control, and
- Safety and health training.

Other resources that are extremely valuable in establishing an electrical safety program are the NFPA 70E, *Standard for Electrical Safety in the Workplace*, Section 110.7, Electrical Safety Program, and the NFPA *Electrical Safety Program Book.*

In Summary

Risk management and assessments are vital to the safety of employees and to the reliability of electrical equipment and systems. If electrical hazards are not identified through analysis and assessments, then employees are at risk of injury or death if an incident were to occur. Electrical equipment and systems safety and reliability are at risk if circuit protective devices are not properly maintained. Electrical safety inspections are necessary in order to verify compliance with regulations and standards. Compliance with the OSHA regulations and NFPA standards will provide a means to reduce accidents, injuries, and fatalities in all segments of industry.

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