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ARC FLASH RISK ASSESSMENT

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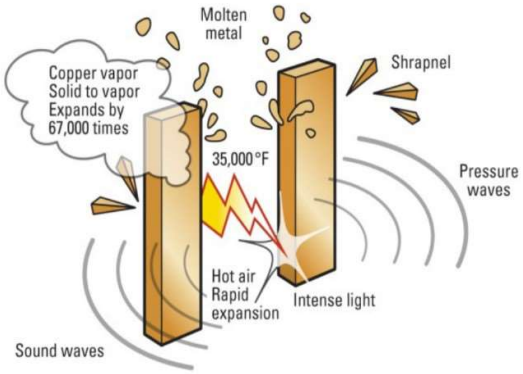
- ## Introduction –

Arc Flash is a source of possible injury or damage to health associated with the release of energy caused by an electric flash.
Arc Flash Hazard is very different from Electric Shock Hazard. Electric shock injury is an outcome of flow of electric current through the body, whereas Arc flash injury is caused by thermal burn to skin. Differentiation between Arc flash hazard and shock hazard is made recently. Both, arc flash hazard and shock hazard are equally deadly. The main line of defence is employed for protection against Shock Hazard but Arc Flash Hazard have remained unnoticed by many of us.

- ## What is an Arc Flash –

During a short circuit event in a power system, current can reach ten thousand amperes. Such high magnitude current instantly melts conductors at the short circuit point and also creates a strong magnetic force. Both of them, in effect, create an air gap at the short-circuit point. As current flows across the air gap, an arc results that can ionise the surrounding air, creating conductive plasma. This is called an arc flash.
Plasma is a form of matter in which many of the electrons wander around freely among the nuclei of the atoms. Plasma has been called the fourth state of matter, the other three being solid, liquid, and gas.



In the event of an arc flash, the initial flash usually establishes a highly conductive plasma that sustains the current. The plasma will conduct as much energy as is available and is only limited by the impedance of the arc and the overall electrical system impedance. This massive energy discharge burns the bus bars or wiring, vaporising the copper or aluminium, and thus causing an explosive volumetric increase. The result is a fiery explosion, possibly leading to serious and fatal injuries to personnel in the vicinity of the arc flash event location.

- ## Factors attributable to Arc Flash –

Human Errors:
Such as touching a test probe to the wrong surface, tools or accessories slipped on live parts of the installation, forgotten tools, dangling wiring, a worker entering the wrong panel. Some work activities such as voltage testing, impedance measurements, fault finding, and
commissioning take place with energized conductors in close proximity, either because they are allowed exceptions or because the activity requires it. Even making the equipment safe to work can expose the worker to a hazard. Although internal arc faults are often caused by human mistakes or ignorance, switchgear designs do affect the probability of making mistakes or touching live parts.

Insulation Failure:
Insulation failures can increase the probability of arc faults as well, obviously due to improper installation, poor maintenance, moisture, whiskers, animals, or even normal wear and tear. Loss of insulating properties resulting from elevated temperatures can be caused by applying the equipment above its continuous rating or from improperly torqued or aligned contact joints. Another cause can be voids in insulation, which eventually lead to failure of the insulation when stressed at high voltages, or the presence of dust, contamination, or moisture on insulating surfaces. These conditions can lead to tracking across insulating surfaces, providing a path for conduction between two different potentials.

Technical Deficiencies:
Arc flash caused by technical deficiencies like inadequate equipment withstanding capacities, etc. might create significant damage.

- ## Arc Flash Event Facts –

At the short-circuit point, a very high temperature is generated instantly. The maximum temperature recorded is 20,000 0C, which is 4 times the sun's surface temperature! This is the highest temperature on the earth.
At such a high temperature –

1. Rapid or sudden expansion of air produces a very strong air pressure wave.
2. All materials are vaporized. With great force, molten metal spreads over a large area.
3. Arc's Explosive Nature Flash can generate a sound wave with a pressure of up to 160 decibels, enough to rip the eardrum.
4. A high-intensity light wave can cause temporary or permanent vision damage.
5. Toxic smoke Molten metal vapours and spray can fill the air and be inhaled by victims.
6. Harmful ultraviolet rays of radiation.

- ## Arc Flash Injury –

Arc flash injuries include external burns (i.e., burns to the skin), internal burns and intoxication from inhaling hot gases and vaporised metal, hearing damage, eye damage, and blindness from the ultraviolet light of the flash, etc.
The severity of the thermal effect of an arc flash is defined by the amount of "incident energy" that a victim, standing at a given distance from the arc, could receive to the skin surface. The "incident energy" is the value calculated that defines the severity of the arc flash. It can be quantified in units of kilojoule/metre2 (kJ/m2), joule/centimetre2 (J/cm2) and calories/centimetre2 (cal/cm2). One cal/cm2 is equal to 4.184 J/cm2 and is equal to 41.84 kJ/m2. Units of cal/cm2 will be used throughout the world, since this is the unit, that is specified to be put on the PPE garment labels according to IEC 61482-2.
Exposure to these extreme temperatures burns the skin directly and causes ignition of clothing, which adds to the burn injury. In addition to causing burns, an arc flash can cause inhalation injuries. When inhalation injuries are combined with external burns, the chance of death can increase significantly. Aside from burns, other hazards from an arc flash include toxic gases, an arc blast, shrapnel, hearing damage due to noise, and temporary or permanent vision loss.
Arc flashes can cause death at distances of 3 metres (10 feet).

- **Severe Consequences of an Electrical Arc Flash –**

Arcing incidents cause huge losses in many instances. Consequences of arc flash event are outlined below-

1. **Injury or death-**
   Arc flash is a deadly electrical hazard. It can cause thermal burn injuries to personnel working on or near live electrical conductors or circuits. The severity of the injuries determines the victim's survival. Burn injuries are very slow to heal and leave lasting physical and mental scars.
   First degree burns are also called superficial epidermal burns. Only the epidermis is affected, and there may be some reddening and slight swelling but no blisters. The next is a second-degree burn or a partial-thickness burn, which affects the second layer of skin, or dermis. The symptoms are similar to those of a first-degree burn, but blistering may occur either immediately or sometime later. Next in severity is a third-degree burn, also called a full thickness burn, which goes through all layers of skin to the subcutaneous tissue (or fat) below. A fourth-degree burn goes through all layers of tissue and affects muscles and bones. The more severe burns often result in nerve damage, which means that the patient may not feel pain, but risks of life-threatening infections are a common feature depending upon how much of the body is affected.
   The inhalation of toxic and superheated products of combustion is an often-overlooked consequence of arc flash. Blindness due to ultraviolet light, thermal burns, and blasts is another outcome. The effects of ultraviolet light can cause cataracts to appear years later, the injuries that the apprentice cited in the introduction caused temporary blindness.
   As a point of reference for incident energy, a 1 second exposure to a heat flux of 5.0J/cm2 (equivalent to 1.2cal/cm2) can cause the onset of a second-degree burn to the skin. This value is used by many standards as the benchmark that defines protection against the thermal effects of arc flash and the threshold of a zone, which is commonly known as the arc flash boundary.
   A victim with 2nd degree burns generally does not suffer a permanent physical injury.

2. **Fines and Compensation Claims-**
   Financial penalties due to fines are not always as severe and eye watering as they should be, but compensation claims can run into many hundreds of thousands of rupees, depending on severity.
   There does not even have to be personal injury to provoke legal action by the authorities. This comes out of the requirement to report an arc flash event (Form A- Accident Reporting may be seen).

3. **Damaged Brand Name-**
   An arc flash incident could potentially threaten the viability of the company. The government authorities begin an investigation into the company and those who were working at the time of the arc flash incident. Senior management requires them to spend countless hours in investigations, discussions, and legal representations to mitigate against the threats of prosecution under the law.
   The message is to be mindful of the damage to your brand that could occur when working on energised equipment.

4. **Severe Equipment Damage-**
   Arc flash could cause severe damage to electrical equipment and sometimes require complete replacement due to the effects of arcing. Replacement of electrical equipment carries a high price tag, not only in terms of cost but also in terms of procurement time and outages. Repairs are not often possible due to a lack of replacement parts.

5. **Lost Production-**
   Very often, the reason cited for working on live equipment is that production is so important that it would not be possible to shut the equipment down to work on it safely. A planned shutdown will stop production for the duration of the work, whereas an electrical flashover in switchgear will result in an unplanned event. In most cases, it is not going to be possible to resume production in a reasonable amount of time if the damage is severe.

6. **Fires-**
   Arc Flash Events, sometimes, convert into electric fire that cause huge losses to property.

- **Electrical Safety Standards –**

In India, the following electrical safety standards are enacted:

1. **Electricity Act 2003**

   Section 146. (Punishment for non-compliance of orders or directions):
   Whoever, fails to comply with any order or direction given under this Act, within such time as may be specified in the said order or direction or contravenes or attempts or abets the contravention of any of the provisions of this Act or any rules or regulations made thereunder, shall be punishable with imprisonment for a term which may extend to three months or with fine, which may extend to one lakh rupees, or with both in respect of each offence and in the case of a continuing failure, with an additional fine which may extend to five thousand rupees for every day during which the failure continues after conviction of the first such offence.

   DRAFT STAGE
   THE ELECTRICITY (AMENDMENT) BILL, 2022 / THE ELECTRICITY (AMENDMENT) RULES, 2023
   146. Whoever, fails to comply with any order or direction given under this Act, within such time as may be specified in the said order or direction or contravenes or attempts or abets the contravention of any of the provisions of this Act or any rules or regulations made thereunder, shall be punishable with fine which may extend to one crore rupees, in respect of each offence and in the case of a continuing failure, with an additional fine which may extend to one lakh rupees for every day during which the failure continues after conviction of the first such offence.

2. **Central Electricity Authority (measures relating to Safety and Electric Supply) Regulations, 2023**

   Chapter III :: General Safety Requirements
   Clause 14: General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric supply lines and apparatus.
   14.2 - Save as otherwise provided in these regulations, the relevant standards including National Electrical Code and National Building Code shall be followed to carry out the purpose of these regulations and where relevant Indian Standards are not available, International Standards shall be followed and in the event of any inconsistency, the provisions of these regulations shall prevail.

3. **National Electrical Code of India 2023 (BIS Standard No. – SP30 : 2023)**

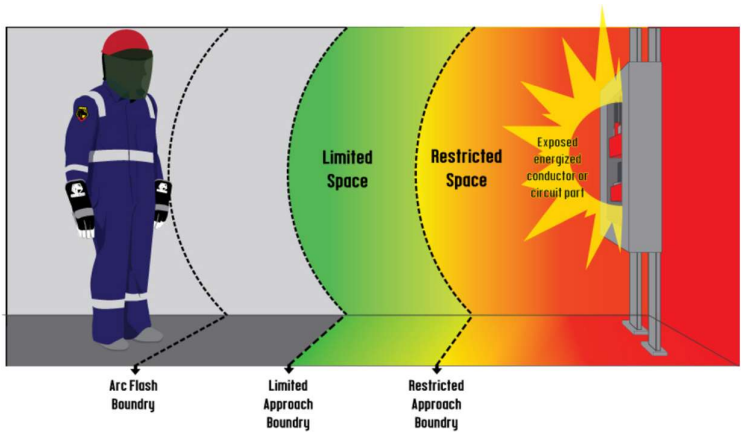
   Part I Section 22 :: SAFETY IN ELECTRICAL WORKS
   - **Clause 6: Administrative Controls to Implement Safety At Work Places**
     6.1.b – Laying down procedure to be adopted while working on electrical installation for various tasks by assessing electrical hazards of shock/arc flash which may arise due to particular task; work environment and/or Human Error
   - **Clause 7: Installation**
     7.5 – To maintain physical clearances from the other services, norms shall be strictly followed. Approach boundaries and arc flash boundaries shall be marked in front of panel boards/equipment/apparatus.
   - **Clause 12: Maintenance of Electrical Installation**
   - **Clause 14: Electrical Hazards Involving Use/Operation And Working On Electrical Installation**
     14.7 - Arc flash risk assessment shall be carried out from the point of view of possibility of occurrence, potential severity of injury, damage to health and collateral damages to system/assets.

As per the above standards, the risk evaluation of Arc Flash Hazard is statutory and mandatory, and the evaluation has to be made as per the guidelines stipulated in the following risk evaluation standards:

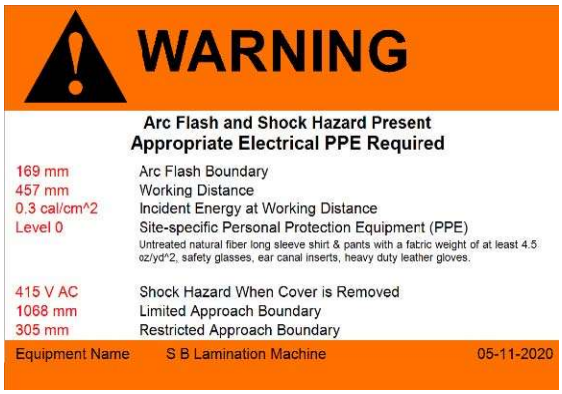
1. **NFPA 70E (2018-22) Standard for Electrical Safety Requirements:**
   This is applicable for employee and workplace safety requirements involving electrical equipment and systems.
2. **IEEE Standard 1584-2018:**
   This offers guidelines for performing arc flash hazard calculations.
   Qualified Person – A person who performs arc-flash hazard calculations must have skills and knowledge related to the construction and operation of the electrical equipment and installation and have experience in power system studies and arc-flash hazard analysis.

Arc flash hazard analyses are performed to identify and quantify potentially dangerous situations and enable the end user to make fact-based decisions rather than assumptions in a matter of personal safety. Arc flash hazard analyses calculate the energy (thermal) released by an arc fault, the arc flash boundary, and the PPE requirement, and the analysis results are used for preparing arc flash equipment labels.

As per the safety standards, implementation of Safety System for Arc Hazard Management is a responsibility of an owner of Electrical Installation.



Approach Boundaries



Labeling Risk Hazard and PPE