# Arc Flash Analysis based on IEEE 1584-2018 and NFPA70E-2018

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**Article History** Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 20 April 2021

**Abstract:** Arc flash is the dangerous hazard, with possible release of energy caused by an electric arc which can cause damage to the equipment and personal. The purpose of the IEEE 1584 and NFPA 70Es is to calculate the energy level and help to achieve the appropriate protection to the working personals. Using IEEE 1584-2018 and NFPA 70E – 2018, we can achieves more accurate calculations and Personal Protective Equipments recommendations compared with IEEE 1584 -2002 and NFPA 70E -2002 with the parameters Open circuit voltage, electrode configuration, bolted fault current, gap width, arc flash duration working distance and enclosure size.

**Keywords:** Arc Flash, IEEE 1581, NFPA 70E, Electrode configuration.

## 1. Introduction

Electric arc is produced in Electrical System due to the opening of energizing conductors, insulation failures, Error caused humans while operating etc…, due to the thermal energy released by the arc [1], temperature and pressure around the are builds up and strike up and cause damage to the things and the living things around it by severe burns and casualties [2], in industries it leads to the plant shutdown, unemployment and financial losses. So it is important to know the thermal energy released by the arc and to determine the safe working area, also the personal protective equipment according to the thermal energy released by the arc.

Energy released by the arc is determined by the standard by using calculation given in the IEEE 1584, the personal protective equipment selection and the safe working area is determined by the NFPA 70E, NFPA 70E is analysis and updated with the duration five years, IEEE 1584 also updated on 2018 for the accurate analysis.

In this paper carry out the Arc Flash Studies of the power system network for the Mylan Laboratories Limited, Unit-8 at Chodavaram, Visakhapatnam. Arc Flash study has been carried out on the electrical system with the objectives of ensure personnel safety against electrical arcs or shocks, Establishing the maximum incident energy at Switchgear, Establishing the Arc flash boundary based on the arc fault current and fault clearing time, Specifying the rating of Hazard / Risk category, Recommendation of appropriate PPE to be Worn during live work.

Arc Flash study was carried out using the latest ETAP version 19.0 (Electrical Transient Analyzer Program) developed by Operation Technology Inc, USA. ETAP is so popular for its capability for modelling of power system networks and analyzing various studies and Real Time simulations.

**Arc Flash Methodology And Calculation**

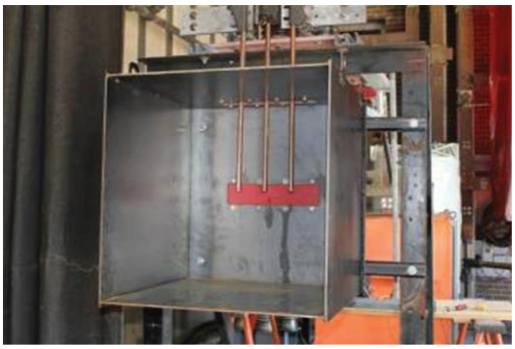
In Arc Flash analysis, analysis and calculation are based on the standards of 1584 and NFPA 70E, which are periodically updated for more accurate analysis, so updating the arc flash analysis very important to calculate the thermal energy released more accurately.

In the calculation based on the IEEE 1584-2002 [3], the thermal energy released is calculated for the 85% expected arcing current. Result of the arcing current having higher incident energy levels and arc current duration also. While using the updated version of IEEE 1584 – 2018 [4], In the incident thermal energy is calculation, arcing current variation factor based on the electrode configuration and it is not by the percentage expected, Compared the arrangements of Electrodes, the horizontal arrangement of electrodes will cause arc flash energy release level compared to the vertical arrangements of electrodes.

For the Voltages 240V and below in three Phase systems, the arcing currents are possible and sustainable with the range of short circuit current of less than 2000A.

So we do the calculation for the voltages for below two levels, working distance and fault clearing range.

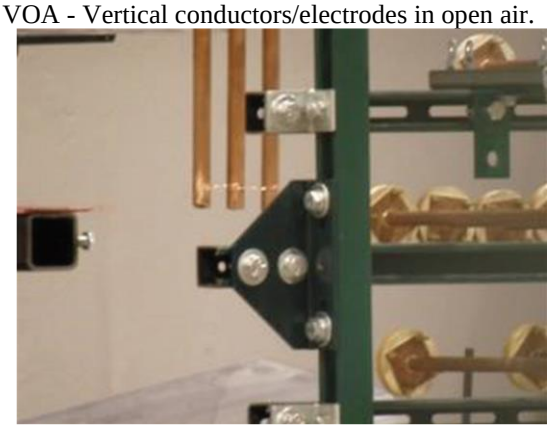
1. $600V < V_{oc} \leq 15kV$ with the frequency of 50 /60HZ,
    1. RMS Symmetrical Bolted fault current value of 200A to 65kA
    2. Gap between conductors are 19.05mm to 254mm
2. $208V < V_{oc} \leq 600V$ with the frequency of 50 /60HZ,
    1. RMS Symmetrical Bolted fault current value of 500 A to 106 000 A
    2. Gap between conductors are 6.35 mm to 76.2 mm.
3. Working distance greater than or equal to 305 mm or 12 inches
4. Fault clearing time is no limit.
5. Electrode Configuration
    1. VCB - Vertical conductors/electrodes inside a metal box/enclosure.



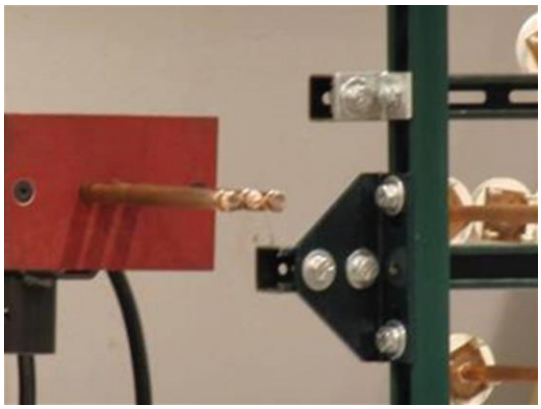
2. HCB – Horizontal conductors/electrodes inside a metal box/enclosure.

3. VCBB -Vertical conductors/electrodes terminated in an insulating barrier inside a metal box/enclosure.

4. VOA - Vertical conductors/electrodes in open air.



5. HOA - Horizontal conductors/electrodes in open air.



**A. Procedures and Calculation:**

Following steps are required to calculate the Arc flash incident energy calculations

1. Determining the arc current
   a. Determine the Electrode configuration.
   b. Determine the final value of arcing current from the following equations.
2. Determine the arc fault clearing time, reasonable assumptions is 2s max.
3. Determine the incident energy by using enclosure correction factor.
4. Determine the Arc Flash Boundary by using enclosure correction factor.
5. Select the appropriate PPE based on the incident energy level, The recommended table as per the NFPA 70E is given here

| Sl.No | Level | Cal/cm$^2$ | PPE Requirements |
|---|---|---|---|
| 1 | 1 | 4 | Minimum 4 cal/cm$^2$ Arc-rated Coverall, Arc-rated face shield or arc flash suit hood, Arc rated jacket, Hard hat liner, Hard hat, Safety glasses or safety goggles, Hearing protection (ear canal inserts), Heavy duty leather gloves, Leather footwear |
| 2 | 2 | 8 | Minimum 8 cal/cm$^2$ Arc-rated Coverall, Arc-rated face shield or arc flash suit hood, Hard hat liner, Arc- rated gloves, Hard hat, Safety glasses or safety goggles, Hearing protection (ear canal inserts), Heavy duty leather gloves, Leather footwear |
| 3 | 3 | 25 | Minimum 25 cal/cm$^2$ Arc-rated coverall- Long Sleeve shirt, Arc-rated arc flash suit Hood & Pant, Arc-rated gloves, Hard hat, Safety glasses or safety goggles, Hearing protection (ear canal inserts) Leather footwear |
| 4 | 4 | 40 | Minimum 40 cal/cm$^2$ Arc-rated coverall- Long Sleeve shirt, Arc rated jacket & pant, Arc-rated arc flash suit Hood & Pant, Arc-rated gloves, Hard hat, Safety glasses or safety goggles, Hearing protection (ear canal inserts) Leather footwear |

**B. Usage of software:**

To avoid human error and faster result we using the software ETAP 19.0.1, which having the updated model of incident energy calculations and recommended PPE as per IEEE 1584 – 2018 and NFPA 70E -2018.

**3. Model, resdult and analysis**

Arc Flash Studies of the power system network for the Mylan Laboratories Limited, Unit-8 at Chodavaram, Visakhapatnam.

- Collecting the system data: This includes the plant single line diagram, equipment details and protective device details. The system model developed for the arc flash study by adding the protective device details and setting provided by Mylan laboratories. single line diagram is provided in annexure A
- Determining the bolted fault current at each switchgear: This involves calculating the RMS value of bolted fault current at each switchgear. The short circuit study is performed to determine the bolted fault current for various operating scenarios.
- Determine the arc fault current: The arc fault current is normally less than the bolted fault current. The software calculates the arc fault current from the bolted fault current.
- Determine the duration of arc fault current: The duration of arc fault current is decided by the fault clearing time. This is determined by the protective device coordination study.

- Select the working distance: The arc flash study always considers the incident energy on the face and body of a person at the working distance. It is not based on the incident energy on hand or arm. The typical working distance is selected from the IEEE 1584-2018. The typical working distance is the sum of the distance of the worker from the front of the panel and the distance of the arc source to the front of the panel. 61 cm is considered as working distance.
- Determine the incident energy for each switchgear at the working distance.
- Determine the flash protection boundary. This is the distance from the arc source within which the incident energy can cause second degree burn. It is based on the incident energy of 1.2 cal/cm2.

**4. Results And Discussion**

Here we given the table of arc flash simulation result of power house 1 example and the result of simulation is provided in the Annexure B.

Based on the Arc flash study and simulation results during incident energy are exceeding the PPE requirements hence live maintenance is not recommended in this condition. Proper LOTO in this respect will aid safety.

From the protection coordination point of view, there is no discrimination between incomer and outgoing feeders in many places and hence it is recommended to revisit the relay coordination studies.

**5. Abbreviations And Definition Of Terms**

| | | |
|---|---|---|
| AFB | - | Arc Flash Boundary |
| B/C | - | Bus Coupler |
| CB | - | Circuit Breaker |
| CT | - | Current Transformer |
| DT | - | Definite Time |
| EI | - | Extremely Inverse |
| FPB | - | Flash Protection Boundaries |
| DG | - | Diesel Generator |
| HV | - | High Voltage |
| I/C | - | Incomer |
| IDMT | - | Inverse Definite Minimum Time |
| IEC | - | International Electro Technical Commission |
| IEEE | - | Institute of Electrical and Electronics Engineers |
| kA | - | Kilo Ampere |
| kV | - | Kilo Volt |
| kW | - | Kilo Watt |
| LV | - | Low Voltage |
| LTI | - | Long Time Inverse |
| LAB | - | Limited Approach Boundary |
| LOTO | - | Lockout-tagout |
| MVA | - | Mega Volt Ampere |
| MW | - | Mega Watt |
| NI | - | Normal Inverse |
| NR | - | Numerical Relay |
| NFPA | - | National Fire Protection Association |
| O/G | - | Outgoing |
| PPE | - | Personal Protective Equipment |
| p.u | - | per unit |
| pf | - | Power Factor |
| RAB | - | Restricted Approach Boundary |
| SLG | - | Single Line to Ground |
| $T_{op}$ | - | Time of operation |
| TMS | - | Time Setting Multiplier |
| VCB | - | Vertical conductors/electrodes inside a metal box/enclosure |
| VI | - | Very Inverse |

a) Arc-Flash:

An electric arc event with thermal energy dissipated as radiant, convective, and conductive heat.

b) Arc-Flash Hazard:

A dangerous condition associated with an electric arc likely to cause possible injury.

c) Arcing Current Or Arc-Fault Current.

A fault current flowing through an electrical arc plasma.

The amount of arcing current is a function of the voltage, available bolted fault current, and the gap between the conductors. Particularly at lower voltages the arcing current can be significantly lower than the available bolted fault current.

d) Bolted Fault Current:

A short-circuit condition that assumes zero impedance exists at the point of the fault.

e) Fault Clearing Time:

The total time between the beginning of a specified overcurrent and the final interruption of the circuit at rated voltage. Syn: arc duration.

f) Incident Energy:

The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electric arc event.

Note 1 - the incident energy is calculated at the working distance. Incident energy increases as the distance from the potential arc source decreases, and the incident energy decreases as the distance increases. See: working distance.

Note 2 - the units used to measure incident energy are joules per square centimeter ($J/cm^2$) or calories per square centimeter ($cal/cm^2$).

g) Flash Hazard Analysis:

A method to determine the risk of personal injury as a result of exposure to incident energy from an electrical arc flash. A study investigating a worker' s potential exposure to arc-flash energy, conducted for the purpose of injury prevention and the determination of safe work practices and the appropriate levels of PPE.

h) Shock Hazard:

A dangerous condition associated with the possible release of energy caused by contact or approach to live parts.

i) Arc Flash Boundary:

A distance from a prospective arc source at which the incident energy is calculated to be 5.0 $J/cm^2$ (1.2 $cal/cm^2$).

j) Limited Approach Boundary:

An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazards exists.

k) Restricted Approach Boundary:

An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electric arc-over combined with inadvertent movement

l) Working Distance:

The distance between the possible arc point and the head and body of the worker positioned in place to perform the assigned task.

m) Hazard/Risk Category:

Quantification of the level of hazard or risk. The Hazard/Risk categories related to arc- flash PPE is as shown in Table 130.7 (C) (16) of NFPA 70E-2018. The typical distances provided in IEEE 1584 - 2018 are used to determine the potential Incident Energy Level exposure for a worker on a given piece of equipment.

**6. References**

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