Arc Flash Calculation Methods

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ARC FLASH CALCULATION METHODS

This course gives an overview of arc flash hazard computations suggested by IEEE and NFPA. All formulas and calculation procedures presented in this course are the property of the IEEE and NFPA. Students are encouraged to consult the standards for additional details.

IEEE STD 1584-2002

The listed methods are suggested by IEEE Standard 1584-2002 in the assessment of arc flash hazard. The empirically derived formulas were developed by IEEE working group on arc flash. These formulas were derived from test results and are applicable for the below listed conditions.

Table 1. Conditions for which the IEEE 1584 formulas are valid

Parameter	Range
Frequencies (Hz)	50 or 60 Hz
System Voltage (kV)	0.208 to 15 kV
Gap between electrodes (mm)	13 to 152 mm
Bolted fault current (kA)	0.7 to 106 kA
Grounding type	Ungrounded, grounded, high resistance grounded
Phases	3 Phase faults
Equipment enclosure type	Open air, box, MCC, panel, switchgear, cables

STEP 1: DETERMINE THE ARCING CURRENT

For low voltage electrical systems (<1 kV), the arc current is determined using formula (1).

$$I_a = 10^{\{K+0.662\ \log(I_{bf})+0.0966V+0.000526G+0.5588V*\log(I_{bf})-0.00304G*\log(I_{bf})\}} \qquad (1)$$

Where

log is the $\log_{10}$

I_a = arcing current (kA)

K = -0.153 open configuration
-0.097 box configuration

I_{bf}= bolted fault current for three phase faults (symmetrical RMS) (kA)

V= system voltage (kV)

G= gap between conductors, (mm)

For medimum voltage electrical systems (>1 kV), the arc current is determined using formula (2)

$$I_a = 10^{\{0.00402+0.983\log(I_{bf})\}} \quad (2)$$

STEP 2: DETERMINE THE NORMALIZED INCIDENT ENERGY

The normalized incident energy, which is derived from 0.2 second arc duration and 610 mm arc distance, is determined using formula (3)

$$E_n = 10^{\{K_1+K_2+1.081*\log(I_a)+0.0011G\}} \quad (3)$$

Where

E_n= incident energy normalized for time and distance (J/cm^2)

K_1=	-0.792	open configuration
	-0.555	box configuration
K_2=	0	ungrounded and high resistance grounded systems
	-0.113	grounded systems
G=		gap between conductors (mm)

STEP 3: EVALUATION OF INCIDENT ENERGY

The normalized incident energy is used to calculate the incident energy at a normal surface at a specific distance and arcing time using the formula (4).

$$E = 4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610}{D}\right)^x \quad (4)$$

Where

E= incident energy (J/cm^2)

C_f= Calculation factor =1.0; voltage >1kV

=1.5; voltage <1kV

t= arcing time (seconds)

D= working distance from arc (mm)

x= distance exponent as shown in Table 3.2

Table 2. Distance factor (x) for different voltages and enclosure models

Enclosure Model	0.208 to 1 kV	>1 to 15 kV
Open air	2	2
Switchgear	1.473	0.973
MCC and Panels	1.641	
Cable	2	2

STEP 4: FLASH PROTECTION BOUNDARY

The flash protection boundary is the distance at which staff without personal protective equipment (PPE) may suffer second-degree injuries that can be cured. It is given with formula (5).

$$D_B = 610 * \left[4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{1}{E_B}\right)\right]^{\frac{1}{x}} \qquad (5)$$

Where

D_B= distance of the boundary from the arcing point (mm)
C_f= calculation factor =1.0; voltage >1 kV
=1.5; voltage <1 kV

E_n= normalized incident energy

E_B= incident energy at the boundary distance (J/cm^2); E_B can be set at 5.0 J/cm^2 (1.2 cal/cm^2) for bare skin

t= arcing time (seconds)

x= the distance factor from Table 2

I_{bf}= bolted fault current (kA)

PROTECTION BOUNDARIES SET BY NFPA 70E - FLASH PROTECTION BOUNDARY

Serious burns caused by arc flash can happen within this boundary unless adequate PPE is used.

- Staff within this boundary must wear adequate PPE regardless of their task.

- The distance from the arc source at which the on-set of a second degree burn happens. 1.2 Cal/cm^2 > 0.1 sec. is conceived as a second degree burn threshold.

- Medical treatment may still be needed if bare skin is brought out to this level of flash. Complete recovery is anticipated.

LIMITED APPROACH BOUNDARY

Limited approach boundary sets a boundary around brought out live parts that may not be violated by “unqualified” staff unless followed by “qualified” staff.

- May be nearer than flash boundary.

- Determined exclusively on the nominal voltage.

RESTRICTED APPROACH BOUNDARY

Restricted approach boundary is boundary near brought out live parts that may be violated only by “qualified” staff using adequate shock prevention methods and tools.

- Concern is a shock hazard.

- Determined exclusively on the nominal voltage.

PROHIBITED APPROACH BOUNDARY

A shock protection boundary to be violated by only “qualified” staff using same protection as if direct contact with live part is projected. Determined exclusively on the system nominal voltage.

NFPA 70E - ARC FLASH BOUNDARY

The theoretical maximum arc power in MW is half the bolted 3-phase fault MVA. This happens when the arc current is 70.7% of the bolted fault current. Starting from this, the flash protection boundary is computed as (6):

$$D_B = \sqrt{2.65 * 1.732 * V * I_{bf} * t} \qquad (6)$$

Where

D_B= distance of the boundary from the arcing points (inches)
V= rated system voltage L-L (kV)
I_{bf}= bolted fault current (kA)
t= arcing time (seconds)

NFPA 70E - INCIDENT ENERGY

Arc in open air – 0.6 kV or less, 16-50 kA short circuit current

$$E = 5271D^{-1.9593}t\left[0.0016 * I_{bf}^2 - 0.0076 * I_{bf} + 0.8938\right]$$

Arc in box – 0.6 kV or less, 16-50 kA short circuit current

$$E = 1038.7D^{-1.4738}t\left[0.0093 * I_{bf}^2 - 0.3453 * I_{bf} + 5.9675\right]$$

Arc in open air – Higher than 0.6 kV

$$E = 793D^{-2}VI_{bf}t$$

Where

E= incident energy (cal/cm^2)

I_{bf}= bolted fault current (kA)