



# Arc Flash Calculation Methods

An Online Continuing Education Course for Engineers

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# 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).

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

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 medium 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<sup>2</sup>)

$K_1$ =    -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).

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

Where



x= the distance factor from Table 2  
I<sub>bf</sub>= 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<sup>2</sup> > 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):

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

Where

D<sub>B</sub>= 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

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

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

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

Arc in open air – Higher than 0.6 kV

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

Where

$E$ = incident energy (cal/cm<sup>2</sup>)

$I_{bf}$ = bolted fault current (kA)

$t$ = arcing time (seconds)

$D$ = working distance from arc (inches)

**NFPA 70E - ANNEX C METHOD**

Table 3. Formulas for arc in box for computing arc current, incident energy and flash protection limits

	V<1kV	1kV<V<5kV	V>5kV
$I_a$ =	$0.85I_{bf} - 0.004I_{bf}^2$	$0.928I_{bf}$	$I_{bf}$
$E$ =	$416 I_a t D^{1.6}$	$21.8 I_a t D^{-0.77}$	$16.5 I_a t D^{-0.77}$
$D_B$ =	$(416I_a t/1.2)^{0.625}$	$(21.8 I_a t/1.2)^{1.3}$	$(16.5 I_a t/1.2)^{1.3}$

The formulas in Table 3 are only applicable to arc in box for short circuit currents in 0.6 kA and 106 kA range.

where

$E$  = incident energy ( $\text{cal}/\text{cm}^2$ )

$I_{bf}$  = bolted fault current (kA)

$I_a$  = arc current (kA)

$t$  = arcing time (seconds)

$D$  = working distance from arc (inches)

$D_B$  = separation of the flash protection boundary from the arcing point (inches)

### NFPA 70E TABLES - FLASH PROTECTION BOUNDARY

NFPA 70E presents a simple method of assessing flash protection boundary. This is presented in Table 4. Information shown in this table is an estimate – the actual arc flash limits may depend upon several factors, such as available fault level and trip settings of the upstream protective equipment. Hence, information shown in this table is not suggested for use.

Table 4. Assessment method for determining flash protection boundary as per NFPA 70E-2003 ROP

Arc Location	System Voltage	Flash Protection Boundary (feet)
Arc in Air	200 to 1000 volts	4
Arc in Enclosure	200 to 1000 volts	
Arc in Enclosure	1000	

### CATEGORY CLASSIFICATION

The NFPA 70E provides Hazard Risk Category Classifications. Information on hazard/risk category ratings and V-rated devices are based on several elements such as voltage, type of device, breaker tripping time or types of task presented elements, voltage testing on control circuits, etc.

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) Hazard Risk Category on limit, but only sets the need of V-rated gloves on several elements such as circuit current, circuit doors. The different fuses, working on live safety grounds, working

An example of what NFPA 70E Hazard Risk Category may look like is presented for two items in Table 5: operating on live elements and voltage testing. The accurate short circuit currents for