IEEE 1584-2018 Guide for Performing Arc-Flash Hazard Calculations Comparative Analysis with IEEE 1584-2002

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Disclaimer

Executive summary

The IEEE 1584 Guide for Performing Arc-Flash Hazard Calculations provides equations for assessing the amount of thermal energy that a worker might receive from electrical equipment in the event of an arc flash. These equations have remained the same since the standard was first published in 2002. Based on the results of more than 1,800 tests, the 2018 edition of the guide provides formulas that are both more accurate and more complex and that take into account, in particular, the conductor configuration at the arc's location as well as the dimensions of the equipment in which it occurs.

This analysis will explain the differences between the 2002 and 2018 versions of the IEEE 1584 standard and measure the impact on results established with the 2002 calculation equations. Special attention must be paid to the configuration of conductors for the equipment analyzed given its impact on incident energy results. Finally, the complexity of the model must reflect the industrial reality: the expert must select, among the proposed parameters, those most representative of, and/or disadvantageous to, the actual installations and the work to be carried out on these.

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Introduction

The IEEE 1584-2018 Guide for Performing Arc-Flash Hazard Calculations was published in December 2018.

This guide, which is recognized by industry, provides calculation equations for determining the amount of thermal energy that a person might receive when working on electrical equipment should an arc flash occur. The results of these calculations for incident thermal energy (cal/cm²) are used to evaluate the gravity of potential hazards during electrical work and to determine the minimum thermal performance values for the personal protective equipment (PPE) that workers must wear. They are also used to determine the distance at which rated arc flash PPE is required to avoid burns as well as to assess risk mitigation measures.

The 2002 edition of the IEEE 1584 standard provided empirical calculation formulas based on the results of over 300 arc flash tests conducted in a laboratory using vertical electrodes in open air or in an enclosure. Minor changes were made to this standard in 2004, 2011 and 2013, but the same equations had been used since the first publication.

Many IEEE papers have been published since 2002 on arc flash hazards, showing that certain parameters not included in the tests used to establish this initial standard could impact the results and lead to incident energy levels greater than those determined with the equations in the IEEE 1584 standard. These disregarded parameters include the actual configuration of the electrodes (conductors/bars) in electrical equipment as well as the vertical configuration tested (vertical electrodes with barriers, horizontal electrodes), the dimension of the enclosure in which the arc flash occurs, and the potential for an arc flash to persist at low voltage (208 V) with lowpower transformers.

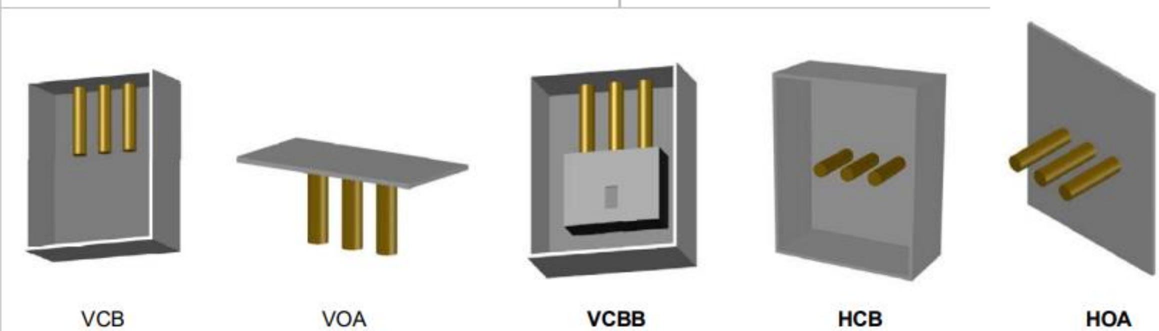
The IEEE 1584-2018 standard provides new empirical formulas that are now based on more than 1,800 tests: these equations are more accurate, but also more complex. The calculation parameters factor in three new electrode configurations (vertical electrodes terminated in an insulating barrier inside an enclosure [VCBB], horizontal electrodes inside an enclosure [HCB], and horizontal electrodes in open air [HOA]), the actual dimensions of the electrical equipment enclosures, and other changes identified in this paper.

The purpose of this document is to present what's new in the 2018 version of the IEEE 1584 standard, using a comparative table to show the differences between the 2002 and 2018 versions.

The second part of this document presents various charts showing the individual effect of the main parameters for the incident energy calculation equations (system voltage, fault current, arc duration or clearing time, working distance, gaps between conductors). The charts also compare the impact of these parameters to their impact in the previous formulas from the IEEE 1584-2002 standard.

The third part of the paper presents the comparative results for actual installations that were analyzed using the 2002 version of the standard and again using the new equations from the 2018 version.

IEEE 1584-2002	IEEE 1584-2018
▪ Enclosure dimension limits: n/a; not a calculation parameter	▪ Enclosure dimension limits: – **Maximum height or width: 1,244.6 mm (49 in)** – **Maximum opening area: 1.549 m² (2,401 in²)** – **Minimum width > 4 x gap between conductors**
▪ Conductor/electrode configurations: – VCB: vertical electrodes inside a metal box – VOA: vertical electrodes in open air	▪ Conductor/electrode configurations: – VCB: vertical electrodes inside a metal box/enclosure – VOA: vertical electrodes in open air – **VCBB: vertical electrodes terminated in an insulating barrier inside a metal box/enclosure** – **HCB: horizontal electrodes inside a metal box/enclosure** – **HOA: horizontal electrodes in open air**



IEEE 1584-2002	IEEE 1584-2018
Parameters with impact on the arcing current	
▪ System voltage ▪ Bolted fault current 3Ø ▪ Conductor configurations: VOA, VCB ▪ Gap between conductors	▪ System voltage ▪ Bolted fault current 3Ø ▪ Conductor configurations: VOA, VCB; **VCBB, HOA, HCB** ▪ Gap between conductors
Parameters with impact on incident energy (cal/cm²)	
▪ System voltage ▪ Arc current ▪ Arc current variation (85 %) for 208 V to 600 V systems ▪ Arc duration / clearing time ▪ Working distance ▪ Conductor configurations: VOA, VCB ▪ Gap between conductors ▪ Equipment type (SWG, MCC, …) – x factor ▪ **System grounding**	▪ System voltage ▪ **Bolted fault current 3Ø** ▪ Arc current ▪ Arc current variation **(VarCf)** for 208 V to **15,000 V** systems ▪ Arc duration / clearing time ▪ Working distance ▪ Conductor configurations: VOA, VCB, **VCBB, HOA, HCB** ▪ Gap between conductors ▪ **Height, width, depth of enclosure**
Incident energy calculations for 240 V or less	
Only if system fed by 125 kVA or higher transformer	**Regardless of transformer power but where available short-circuit current is ≥ 2,000 A**

IEEE 1584-2002	IEEE 1584-2018
Impact of enclosure size	
▪ With the distance x factor based on: – System voltage – Equipment type (SWG, MCC, …)	▪ With the **correction factor (CF)** based on: – System voltage – **Conductor configurations: VOA, VCB, VCBB** – **Height, width, depth of enclosure**
Impact of enclosure depth	
▪ Not considered	▪ **Only if system voltage is less than 600 V** – **Typical depth: > 203.2 mm (8 in)** – **Shallow depth: ≤ 203.2 mm (8 in)**
Arc current variation	
▪ Only at low voltage (< 1,000 V): $I_{arc\ min} = 85\%\ I_{arc}$	▪ From **208 V to 15 kV** and depending on: – **System voltage** – **Conductor configuration: VOA, VCB, VCBB, VOA, HOA**
Calculation method for systems outside the model's range	
▪ Recommendation to use Lee's empirical formula provided in the standard	▪ **No reference to Lee's formula** ▪ **The existence of alternative methods of calculation is indicated, but no recommendation is made.**

IEEE 1584-2002	IEEE 1584-2018
Single-phase systems	
▪ Not covered by the standard	▪ Although not covered by the standard, it states that (s. 4.11): – **The equations provided by the standard can be used with the single-phase bolted current and the voltage of the single-phase system (Ø-T or Ø-Ø) and the protective device opening time.** – **The incident energy result is expected to be conservative.**
DC systems	
▪ Not covered by the standard	▪ Not covered by the standard **but refers to IEEE publications providing some guidance for energy calculation.**
System grounding	
▪ Incident energy depends on system grounding (grounded, ungrounded or high-resistance grounded systems).	▪ **Incident energy is independent of system grounding.**

Modeling Parameter Sensitivity Analysis

This section presents a sensitivity analysis for modelling parameters with an impact on incident energy (cal/cm²). The following charts compare the effect of changes in a given parameter on the evaluation model when the other parameters stay the same. Additionally, the same chart for a given voltage level shows the effect of this variation based on conductor configuration (VOA, HOA, VCB, VCBB and HCB) and compares it to the results obtained with the IEEE 1584-2002 model.

For the purpose of comparisons with industrial installations, the following analysis parameters were selected for the two configurations analyzed.

Table 2: Analysis parameters

Voltage	600 V	13,800 V
Bolted fault current 3Ø	35 kA	15 kA
Arc duration / clearing time	10 ms	100 ms
Working distance	46 cm (18 in)	91 cm (36 in)
Electrode gap	25 mm	152 mm
Enclosure depth	Typical	Typical
Enclosure size	304.8 x 355.6 mm	914.4 x 914.4 mm

- Arcing current Iarc (kA) vs Bolted fault current 3Ø: Ibf (kA) (Charts 1 and 2)
- Incident energy E (cal/cm²) vs Bolted fault current 3Ø: Ibf (kA) (Charts 3 and 4)
- Incident energy E (cal/cm²) vs Arc duration: Tarc (ms) (Charts 5 and 6)
- Incident energy E (cal/cm²) vs Working distance: Darc (mm) (Charts 7 and 8)
- Incident energy E (cal/cm²) vs Gap between electrodes: Gap (mm) (Charts 9 and 10)

I_{arc} sensitivity as a function of I_{bf}

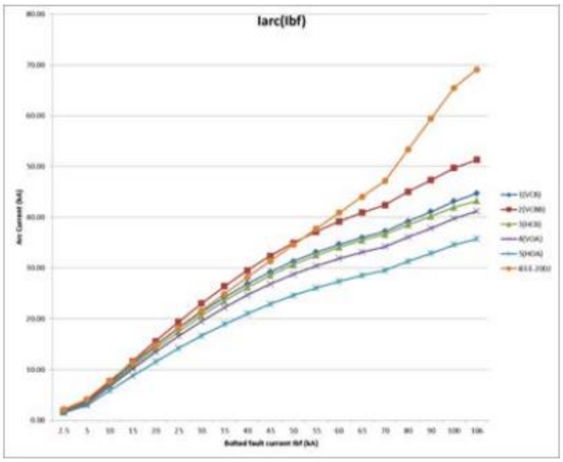


Chart 1: 600 V 25 mm – Iarc (Ibf)

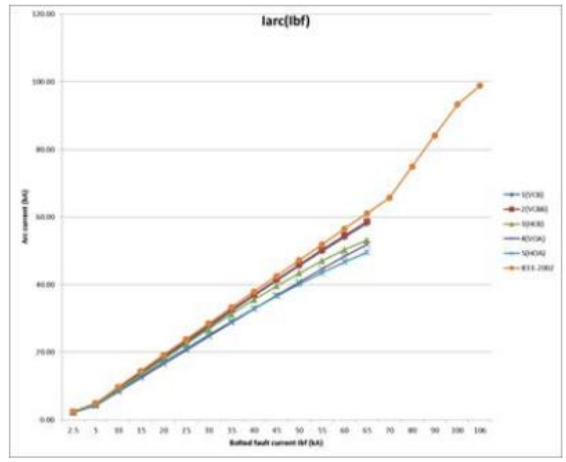


Chart 2: 13,800 V – Iarc (Ibf)

E sensitivity as a function of I_{bf}

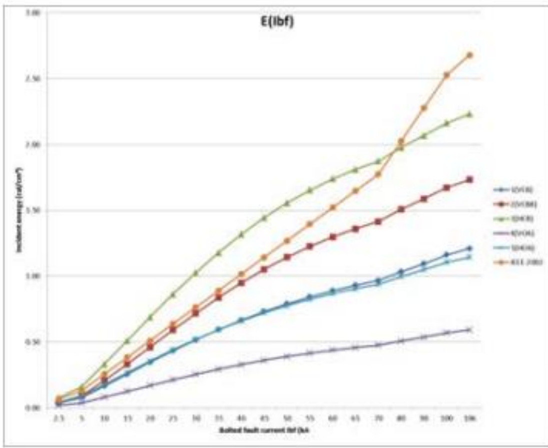


Chart 3: 600 V 25 mm – E (Ibf)

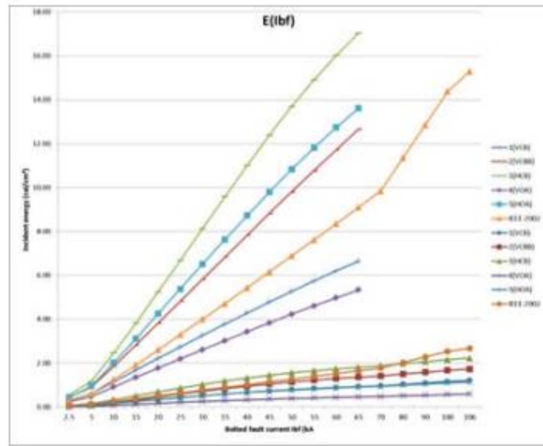


Chart 4: 13,800 V – E (Ibf)

E sensitivity as a function of T_{arc}

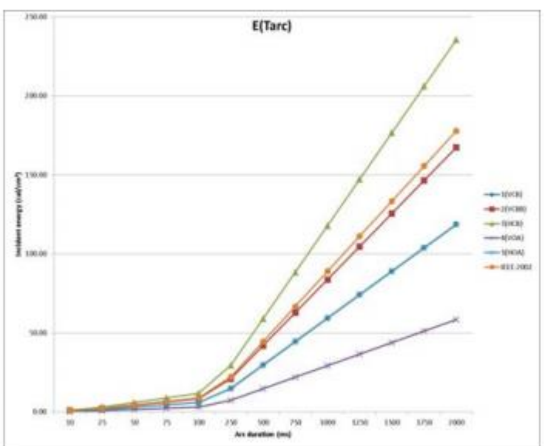


Chart 5: 600 V 25 mm – E (Tarc)

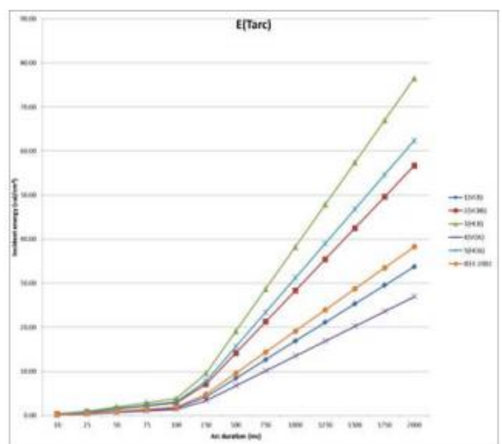


Chart 6: 13,800 V – E (Tarc)

E sensitivity as a function of D

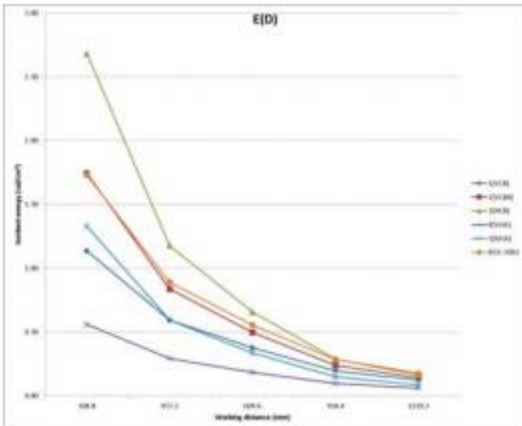


Chart 7: 600 V 25 mm – E (D)

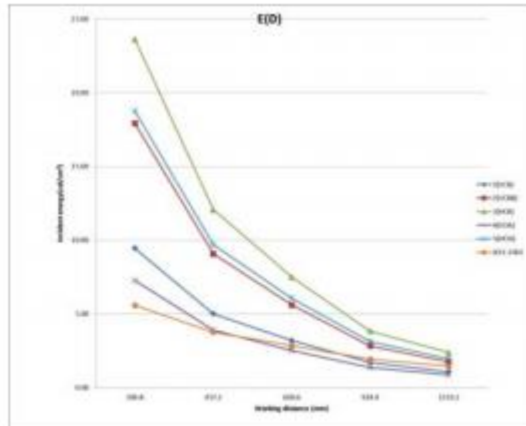


Chart 8: 13,800 V – E (D)

E sensitivity as a function of GAP

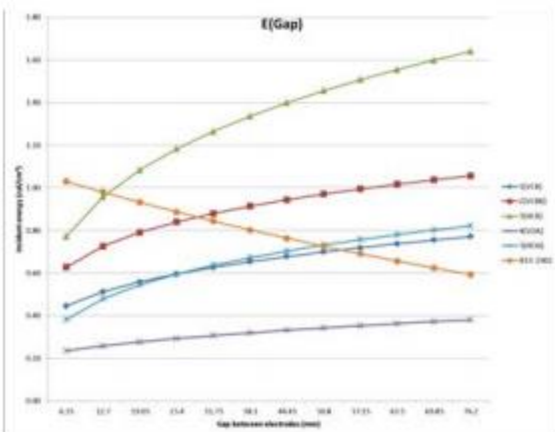


Chart 9: 600 V 25 mm – E (GAP)

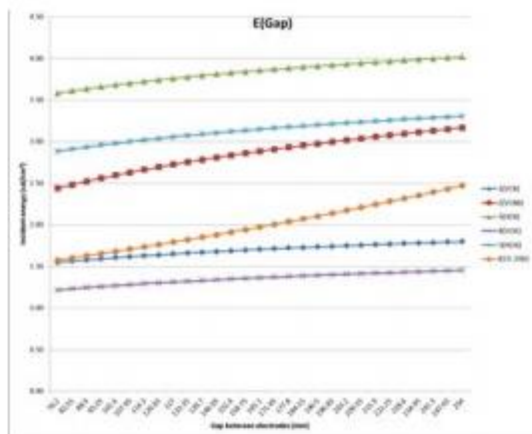


Chart 10: 13,800 V – E (GAP)

Variation in incident energy

The table below shows the effect of doubling the fault current, clearing time, working distance, and gap between conductors on incident energy where other parameters are constant. This analysis was conducted with the IEEE 1584-2002 and -2018 equations for three configurations of electrodes in an enclosure.

	Voltage	208 V	600 V-25 mm	600 V-32 mm	4 160 V	13800 V
		x En	x En	x En	x En	x En
2 x Ibf	IEEE2002	1.8	2.0	2.0	2.1	2.1
	VCB	2.2	1.9	1.9	2.0	1.9
	VCBB	2.4	2.1	2.1	2.1	2.1
	HCB	2.1	1.9	1.9	2.1	2.1
2 x Tarc	IEEE2002	2.1	2.0	2.0	2.0	2.0
	VCB	2.1	2.0	2.0	2.0	2.0
	VCBB	2.1	2.0	2.0	2.0	2.0
	HCB	2.0	2.0	2.0	2.0	2.0
2 x D	IEEE2002	0.3	0.3	0.4	0.5	0.5
	VCB	0.3	0.3	0.3	0.3	0.3
	VCBB	0.3	0.3	0.3	0.3	0.3
	HCB	0.3	0.2	0.2	0.3	0.3
2 x Gap	IEEE2002	1.0	0.8	0.8	1.2	1.5
	VCB	1.0	1.2	1.2	1.1	1.1
	VCBB	1.0	1.2	1.2	1.1	1.2
	HCB	1.1	1.2	1.2	1.1	1.1

Analysis and comments on results

In light of the charts and tables presented earlier, certain general comments can be formulated:

- Arc currents based on fault current:
  - For a given 3Ø fault current, the arc current increases based on conductor configuration as follows: HOA < VOA < HCB < VCB < VCBB.

  - At medium voltage, the arc currents obtained with the IEEE 1584-2018 model are weaker than those with the 2002 version regardless of conductor configuration.
- Incident energy based on Ibf, Tarc, D and GAP:
  - For each of these four parameters, incident energy increases based on conductor configuration as follows: VOA < HOA < VCB < VCBB < HCB at low voltage and VOA < VCB < VCBB < HOA < HCB at medium voltage.
  - With the 2018 model, incident energy for an HCB configuration is greater than that evaluated with the 2002 model.
  - At medium voltage, the 2018 model also yields incident energy greater than the 2002 model for a VCBB configuration.
  - The same orders of magnitude (rules of thumb) used with the 2002 equations can be used with the 2018 equations where other parameters are constant:
    - Incident energy increases proportionately to the fault current and the clearing time.
    - Incident energy decreases exponentially with working distance (1/Dint.).
    - Incident energy increases very little as a function of the gap between conductors (GAP).

Comparative Results for Industrial Installations

To concretely assess the impact of the 2018 calculation guide on the analyses conducted with the 2002 version, this section presents a few comparative results for arc flash hazard analyses that BBA recently carried out for industrial installations.

Comparative results tables are also presented to show impacts for the dimensions of certain equipment found in industrial installations versus the results from equations in the IEEE 1584- 2002 standard and in the IEEE 1584-2018 standard using the proposed standard dimensions.

13.8 kV systems

Equipment Identification	Equipment Location	Arc Flash Calculation Method	Config.	Voltage (kV)	Bolted Fault Current (kA)	Average Arcing Current (kA)	Arc Duration (sec.)	Electrode Gap (mm)	Box Width (mm)	Box Height (mm)	Incident Energy at Working Distance 0.46 (m) (cal/cm^2)	0.61 (m)	0.91 (m)	Flash Protection Boundary $1.2\ cal/cm^2$ (m)
13.8 kV MV SWG	Incoming BRK	IEEE-2002	N/A	13.8	10.10	9.80	0.17	152	N/A	N/A	5.5	4.2	2.8	2.19
		IEEE-2018	VCB	13.8	10.10	9.46	0.17	152	743.0	1143.0	5.8	3.7	2.0	1.25
			VCBB	13.8	10.10	9.68	0.17	152	743.0	1143.0	10.3	6.4	3.2	1.65
			HCB	13.8	10.10	9.11	0.17	152	743.0	1143.0	13.4	8.3	4.3	1.96
	Feeder BRK	IEEE-2002	N/A	13.8	10.10	9.80	0.14	152	N/A	N/A	4.4	3.4	2.3	1.75
		IEEE-2018	VCB	13.8	10.10	9.46	0.14	152	743.0	1143.0	4.8	3.1	1.6	1.10
			VCBB	13.8	10.10	9.68	0.14	152	743.0	1143.0	8.5	5.2	2.7	1.47
			HCB	13.8	10.10	9.11	0.14	152	743.0	1143.0	11.1	6.9	3.5	1.74
13.8-0.6 kV TRF	Primary	IEEE-2002 Lee	N/A	13.8	10.10	10.10	0.07	N/A	N/A	N/A	22.3	12.7	5.7	1.98
		IEEE-2018	HCB	13.8	10.10	9.02	0.07	254	914.4	914.4	5.8	3.6	1.9	1.19
	Secondary	IEEE-2002 Lee	N/A	0.6	29.21	29.21	0.35	N/A	N/A	N/A	14.8	8.4	3.8	1.62
		IEEE-2018	HCB	0.6	29.21	17.91	0.35	254	914.4	914.4	72.3	40.3	17.7	3.44
	Secondary Maintenance	IEEE-2002 Lee	N/A	0.6	29.21	29.21	0.07	N/A	N/A	N/A	2.8	1.6	0.7	0.70
		IEEE-2018	HCB	0.6	29.21	17.91	0.07	254	914.4	914.4	14.5	8.1	3.5	1.56

600 V–208 V systems

Equipment Identification	Equipment Location	Arc Flash Calculation Method	Config.	Voltage (kV)	Bolted Fault Current (kA)	Average Arcing Current (kA)	Arc Duration (sec.)	Electrode Gap (mm)	Box Width (mm)	Box Height (mm)	Incident Energy at Working Distance 0.46 (m) (cal/cm^2)	0.61 (m)	0.91 (m)	Flash Protection Boundary $1.2\ cal/cm^2$ (m)
4.16-0.6 kV TRF	Primary	IEEE-2002 Lee	N/A	4.16	16.17	16.17	0.07	N/A	N/A	N/A	11.1	6.3	2.8	1.40
		IEEE-2018	HCB	4.16	16.17	13.94	0.07	254	914.4	914.4	9.5	5.8	2.9	1.52
	Secondary	IEEE-2002 Lee	N/A	0.6	22.31	22.31	0.30	N/A	N/A	N/A	9.8	5.6	2.5	1.31
		IEEE-2018	HCB	0.6	22.31	12.11	1.50	254	914.4	914.4	206.0	115.0	50.5	5.77
600 V LV SWG	Incoming BRK	IEEE-2002	N/A	0.6	22.31	13.21	1.10	32	N/A	N/A	61.6	40.6	22.5	6.66
		IEEE-2018	VCB	0.6	22.31	15.95	0.70	32	558.8	558.8	27.4	17.3	9.1	3.24
			VCBB	0.6	22.31	17.14	0.55	32	558.8	558.8	29.0	17.3	8.3	2.66
			HCB	0.6	22.31	15.21	0.90	32	558.8	558.8	72.8	40.6	17.4	3.46
	Feeder BRK	IEEE-2002	N/A	0.6	22.31	15.54	0.18	32	N/A	N/A	12.0	7.9	4.4	2.20
		IEEE-2018	VCB	0.6	22.31	18.10	0.18	32	558.8	558.8	7.9	5.0	2.6	1.50
			VCBB	0.6	22.31	19.20	0.18	32	558.8	558.8	10.9	6.5	3.1	1.55
			HCB	0.6	22.31	17.50	0.18	32	558.8	558.8	16.8	9.4	4.1	1.68
600 V Equipment	MCC	IEEE-2002	N/A	0.6	22.16	16.38	0.05	25	N/A	N/A	3.6	2.3	1.2	0.90
		IEEE-2018	VCBB	0.6	22.16	19.34	0.05	25	508.0	304.8	3.0	1.8	0.9	0.75
	Disc. Switch	IEEE-2002	N/A	0.6	17.35	13.06	0.01	25	N/A	N/A	0.6	0.4	0.2	0.29
		IEEE-2018	VCBB	0.6	17.35	15.13	0.01	25	216	540	0.4	0.3	0.1	0.26
	Panelboards	IEEE-2002	N/A	0.6	21.47	15.89	0.01	25	N/A	N/A	0.7	0.4	0.2	0.33
		IEEE-2018	VCBB	0.6	21.47	18.74	0.01	25	304.6	304.8	0.6	0.3	0.2	0.30
600-208 V TRF	Primary	IEEE-2002 Lee	N/A	0.6	17.35	17.35	0.01	N/A	N/A	N/A	0.3	0.1	0.1	0.21
		IEEE-2018	HCB	0.6	17.35	10.88	0.01	254	914.4	914.4	1.2	0.7	0.3	0.46
	Secondary	IEEE-2002 Lee	N/A	0.208	4.72	4.72	0.01	N/A	N/A	N/A	0.0	0.0	0.0	0.06
		IEEE-2018	HCB	0.208	4.72	1.22	0.01	254	914.4	914.4	0.1	0.1	0.0	0.15
DP 208 V	DP	IEEE-2002	N/A	0.208	4.50	2.11	2.00	25	N/A	N/A	12.2	7.7	4.0	1.89
		IEEE-2018	VCB	0.208	4.50	1.92	2.00	25	304.6	304.8	8.4	5.3	2.8	1.55

Impact of enclosure size

600 V disconnect switch

VCBB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy 457 mm (cal/cm^2)	Incident Energy Pu	Flash Protection Boundary 1.2 cal/cm^2 (mm)	Flash Protection Boundary Pu
600 V Disconnect Switch	DisconnectSwitch	IEEE-2002	N/A	1.2	120%	448	111%
	Typical Disc. Switch	IEEE-2018	VCBB	1.0	100%	404	100%
	30 A			1.0	100%	404	100%
	60 A			1.0	100%	404	100%
	100 A			1.0	99%	401	99%
	200 A			0.9	94%	389	96%
	400 A			0.8	84%	367	91%
	600 A			0.8	84%	367	91%
	800 A			0.8	82%	363	90%
	1200 A			0.8	82%	363	90%

HCB Configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy 457 mm (cal/cm^2)	Incident Energy Pu	Flash Protection Boundary 1.2 cal/cm^2 (mm)	Flash Protection Boundary Pu
600 V Disconnect Switch	DisconnectSwitch	IEEE-2002	N/A	1.2	85%	448	92%
	Typical Disc. Switch	IEEE-2018	HCB	1.4	100%	486	100%
	30 A			1.4	100%	486	100%
	60 A			1.4	100%	486	100%
	100 A			1.4	99%	485	100%
	200 A			1.3	96%	477	98%
	400 A			1.2	90%	462	95%
	600 A			1.2	90%	462	95%
	800 A			1.2	89%	459	94%
	1200 A			1.2	89%	459	94%

600 V motor control centre (MCC)

VCBB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy 457 mm (cal/cm^2)	Incident Energy 457 mm Pu	Flash Protection Boundary 1.2 cal/cm^2 (mm)	Flash Protection Boundary 1.2 cal/cm^2 Pu
600 V MCC	MCC	IEEE-2002	N/A	1.2	120%	448	111%
	Typical MCC	IEEE-2018	VCBB	1.0	100%	404	100%
	NEMA 1 MCC			1.0	100%	404	100%
	NEMA 2 MCC			1.0	100%	404	100%
	NEMA 3 MCC			0.9	93%	388	96%
	NEMA 4 MCC			0.9	91%	384	95%
	NEMA 5 MCC			0.8	88%	376	93%
	NEMA 6 MCC			0.8	84%	369	91%

HCB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy 457 mm (cal/cm^2)	Incident Energy 457 mm Pu	Flash Protection Boundary 1.2 cal/cm^2 (mm)	Flash Protection Boundary 1.2 cal/cm^2 Pu
600 V MCC	MCC	IEEE-2002	N/A	1.2	85%	448	92%
	Typical MCC	IEEE-2018	HCB	1.4	100%	486	100%
	NEMA 1 MCC			1.4	100%	486	100%
	NEMA 2 MCC			1.4	100%	486	100%
	NEMA 3 MCC			1.3	96%	476	98%
	NEMA 4 MCC			1.3	95%	473	97%
	NEMA 5 MCC			1.3	93%	468	96%
	NEMA 6 MCC			1.2	90%	463	95%

600 V low-voltage switchgear (LV SWG)

VCBB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy 457 mm (cal/cm²)	Incident Energy Pu	Flash Protection Boundary 1.2 cal/cm² (mm)	Flash Protection Boundary Pu
600 V LV SWG	LV SWG	IEEE-2002	N/A	6.8	114%	1983	134%
	Typical LV SWG	IEEE-2018	VCBB	6.0	100%	1484	100%
	Masterpact 1200 A			5.8	96%	1454	98%
	Masterpact 4000 A			5.0	83%	1342	90%
	Magnum DS 1200 A			5.8	96%	1454	98%
	Magnum DS 4000 A			5.3	88%	1380	93%
	ITE K1600			5.7	94%	1436	97%
	ITE K4000			5.1	84%	1351	91%

HCB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy 457 mm (cal/cm²)	Incident Energy Pu	Flash Protection Boundary 1.2 cal/cm² (mm)	Flash Protection Boundary Pu
600 V LV SWG	LV SWG	IEEE-2002	N/A	6.8	83%	1983	126%
	Typical LV SWG	IEEE-2018	HCB	8.2	100%	1568	100%
	Masterpact 1200 A			8.0	98%	1552	99%
	Masterpact 4000 A			7.3	89%	1485	95%
	Magnum DS 1200 A			8.0	98%	1552	99%
	Magnum DS 4000 A			7.5	92%	1508	96%
	ITE K1600			7.9	97%	1541	98%
	ITE K4000			7.4	90%	1491	95%

4,160 V motor control centre (MCC)

VCBB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy 457 mm (cal/cm^2)	Incident Energy 457 mm Pu	Flash Protection Boundary 1.2 cal/cm^2 (mm)	Flash Protection Boundary 1.2 cal/cm^2 Pu
4160 V MCC	MCC	IEEE-2002	N/A	2.8	92%	2215	141%
	Typical MCC	IEEE-2018	VCBB	3.1	100%	1568	100%
	Ampgard			2.8	92%	1490	95%
	Motorpact			2.9	95%	1523	97%

HCB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy 457 mm (cal/cm^2)	Incident Energy 457 mm Pu	Flash Protection Boundary 1.2 cal/cm^2 (mm)	Flash Protection Boundary 1.2 cal/cm^2 Pu
4160 V MCC	MCC	IEEE-2002	N/A	2.8	62%	2215	124%
	Typical MCC	IEEE-2018	HCB	4.5	100%	1785	100%
	Ampgard			4.3	94%	1728	97%
	Motorpact			4.4	97%	1750	98%

13,800 V breaker

VCBB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy		Flash Protection Boundary	
				457 mm		1.2 cal/cm^2	
				(cal/cm^2)	Pu	(mm)	Pu
13800 V Breaker	Breaker	IEEE-2002	N/A	7.5	88%	5976	203%
	Typical Breaker	IEEE-2018	VCBB	8.6	100%	2948	100%
	GE PowerVac			8.3	97%	2899	98%
	MG Fluarc 1200 A			8.6	100%	2879	98%

HCB configuration

Equipment Location	Equipment Type	Arc Flash Calculation Method	Config.	Incident Energy		Flash Protection Boundary	
				457 mm		1.2 cal/cm^2	
				(cal/cm^2)	Pu	(mm)	Pu
13800 V Breaker	Breaker	IEEE-2002	N/A	7.5	65%	5976	167%
	Typical Breaker	IEEE-2018	HCB	11.5	100%	3583	100%
	GE PowerVac			11.4	99%	3552	99%
	MG Fluarc 1200 A			11.5	100%	3541	99%

Analysis and comments on results

The results presented in the above analysis tables confirm the comments on the parameter sensitivity analysis in the previous section. The decline or increase in certain parameters can lead to the reverse effect on other parameters. These combinations mean that the differences observed with the results established with the 2002 standard can be mitigated or amplified with the equations in the 2018 version. The performance of the protective device(s) upstream from the arc fault is the most obvious case. For a given fault current, depending on the conductor (bar) configuration, the arc current may, for example, be weaker than that established with the 2002 model, but may increase clearing time if the upstream protection is not instantaneous or definite-time.

Nonetheless, we can generally predict that:

- for an HCB configuration, the 2018 incident energy will be higher than the 2002 level at low and medium voltages;
- for a VCBB configuration, the 2018 incident energy is lower than the 2002 level at low voltage, more or less the same at 4.16 kV, and higher at 13.8 kV

Conclusion

The IEEE 1584-2018 standard provides new, more accurate empirical formulas because they are based on a significant number of tests as well as on conductor configurations representative of electrical installations. However, the equations and the calculation methodology are far more complex and involve a higher number of input parameters that affect incident energy results (cal/cm²).

Three key elements in this new edition of the standard are a challenge when analyzing arc flash hazards:

1. Configuration/orientation of conductors/electrodes
   - VCB: Vertical conductors/electrodes inside a metal box/enclosure
   - VOA: Vertical conductors/electrodes in open air
   - VCBB: Vertical conductors/electrodes terminated in an insulating barrier inside a metal box/enclosure
   - HCB: Horizontal conductors/electrodes inside a metal box/enclosure
   - HOA: Horizontal conductors/electrodes in open air
2. Dimension of enclosures
   - Width/height/depth of the enclosure;
3. Analysis of 120/208 V and 120-240 V distribution
   - Distribution where the fault level is greater than 2 kA.

These new inputs will have to be included in future studies and will require more effort for electrical installation surveys in order to factor in the specificities of the installed equipment. It will also be necessary to analyze the configuration of the conductors and sets of bars for the range of equipment with which workers may come into contact in the course of their work. Finally, the complexity of the model must reflect the industrial reality: the expert must select, among the proposed parameters, those most representative of, and/or disadvantageous to, the actual installations and the work to be carried out on these.

References

1. 1584-2018 IEEE Guide for Performing Arc-Flash Calculations
2. 1584-2002 IEEE Guide for Performing Arc-Flash Calculations
3. Z462-18 Workplace Electrical Safety

About our expert(s)

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Joël Sourceaux has been working at BBA in consulting engineering since October 1994 and became partner in January 2000. He holds over twenty years of experience in high-, medium- and low-voltage power systems in the energy, mining, petrochemical and paper industries.

Mr. Sourceaux is an expert in power systems studies, such as short-circuit and protection application and coordination studies as well as electrical hazard analyses. He has performed preliminary studies (master plans, preliminary engineering) and has been responsible for the design and detailed engineering of various multidisciplinary projects. He also participated in the supervision, testing and commissioning of many projects.

He has been specializing in arc flash hazard analyses for over fifteen years (NFPA 70E and CSA Z462 standards) and also provides training in this area as well as training in health and safety at electrical installations.

Mr. Sourceaux has been in charge of the systems studies group for over four years and is currently serving as expert, Integration Engineer and Project Manager.

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