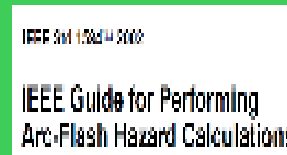
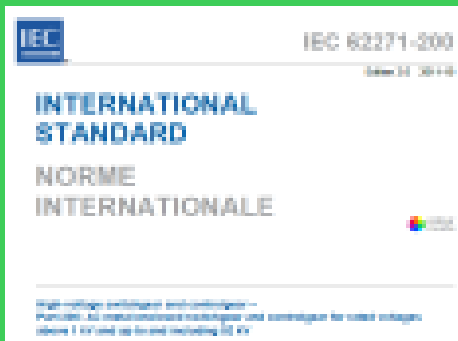
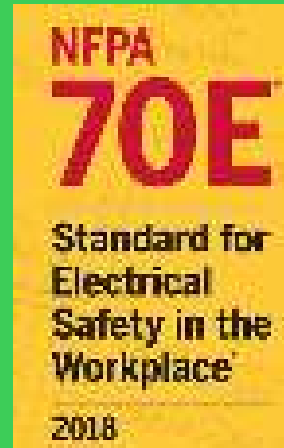
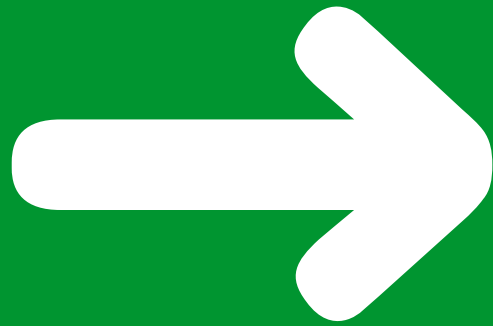


Switchgear Internal Arc Protection In Correlation With Arc Flash

Engr Dionisio N. Bacudio Jr., PEE



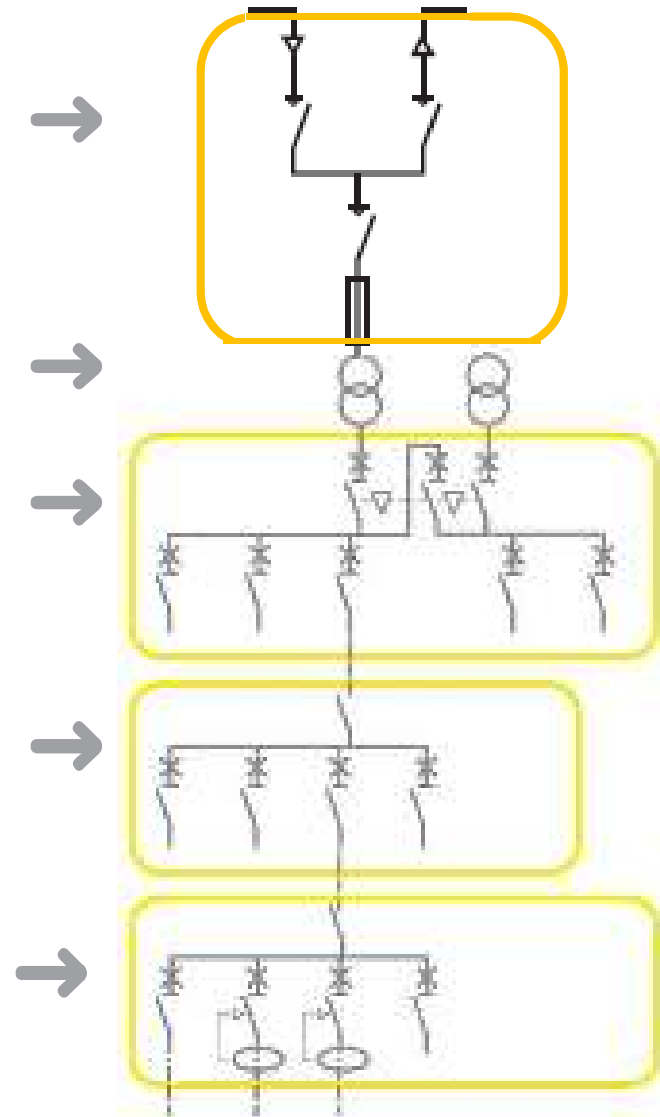
	AGENDA
1	Overview of LV and HV Switchgears
2	Understanding Internal Arc
3	IEC TR on Internal Arc for LV Swgr
4	LV Swgr Internal Arc Protection Design
5	IEC Standard for HV Switchgear on Internal Arc
6	Design on Internal Arc protection for HV Switchgears
7	Arc Flash Protection



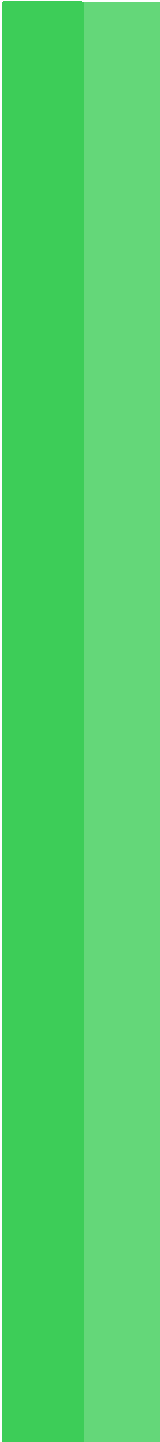
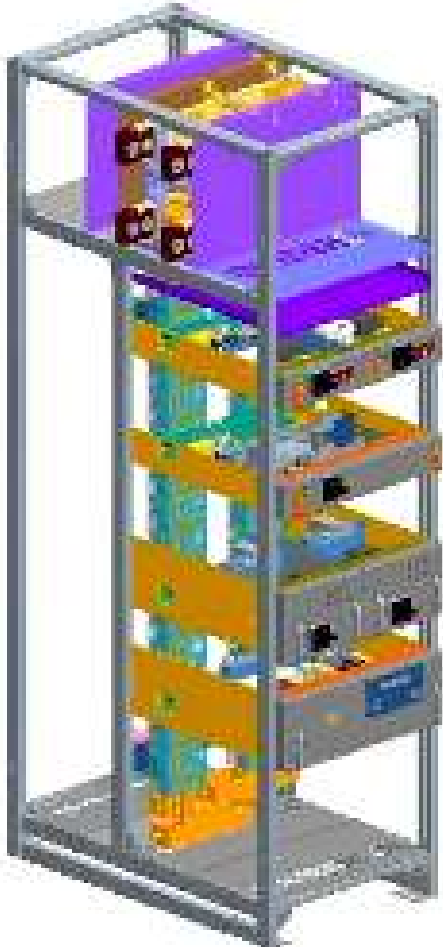
1. Overview of LV and HV Switchgears

Electrical Distribution System -SLD

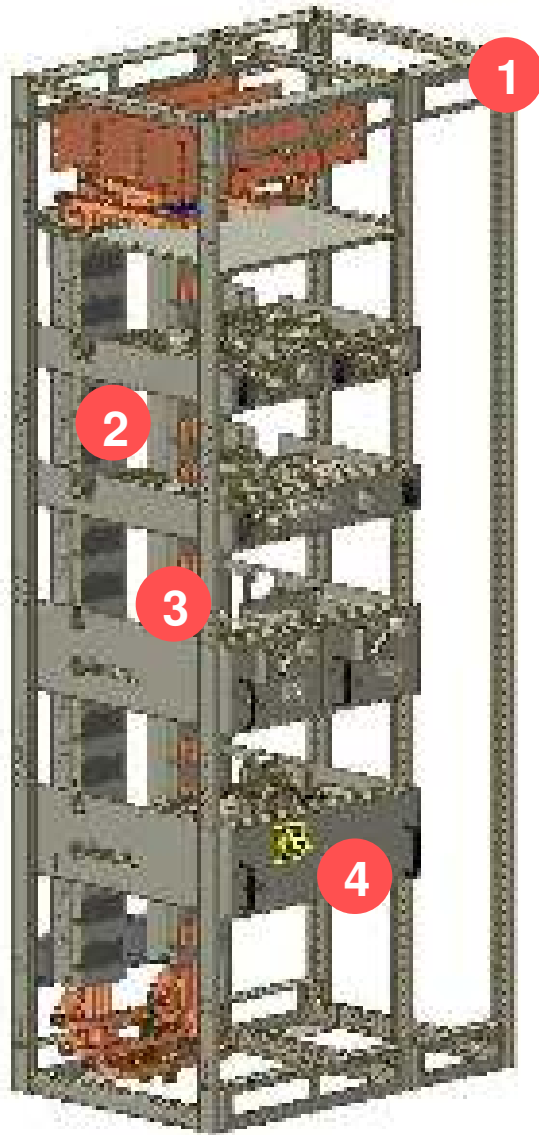
- **HV Switchgear**
- Electrical SCADA / EMCS / PMS
- Transformers – Cast Resin, Oil
- **Main LV Panels – up to 6300A**
- Synchronizing Panels, ATS Panels
- **Motor Control Centers**
- **Sub Main Switchboards**
- **Final Distribution Boards**
- Power Factor Correction & Harmonic Filtering



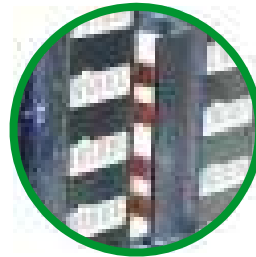
LV Switchgear Overview



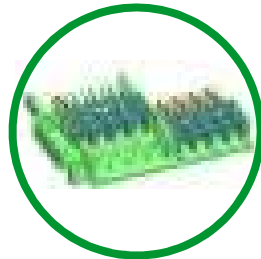
A single architecture



1 Frame



2 Busbars

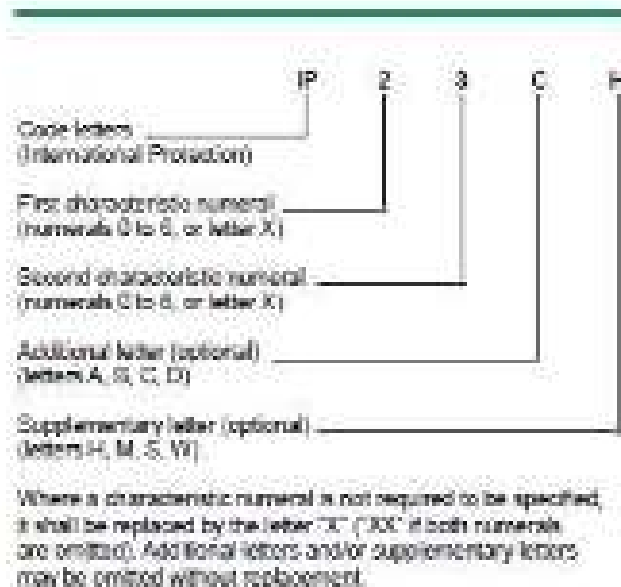


3 Power Connection



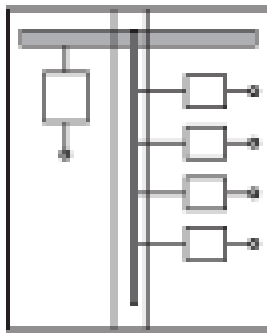
4 Drawer

Additional Letter and Supplementary letter

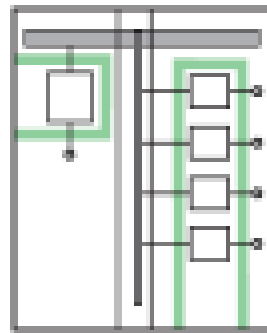


Element	Numerals or letters	Meaning for the protection of equipment	Meaning for the protection of persons
Code letters	IP		
First characteristic numeral	<ul style="list-style-type: none"> 0 (non-protected) 1 ≥ 50 mm diameter 2 ≥ 12.5 mm diameter 3 ≥ 2.5 mm diameter 4 ≥ 1.0 mm diameter 5 Dust-protected 6 Dust-tight 	<ul style="list-style-type: none"> Against ingress of solid foreign objects 	<ul style="list-style-type: none"> Against access to hazardous parts with (non-protected) Back of hand Finger Tool Wire Wire Wire
Second characteristic numeral	<ul style="list-style-type: none"> 0 (non-protected) 1 Vertically dripping 2 Dripping (15° tilted) 3 Spraying 4 Splashing 5 Jetting 6 Powerful jetting 7 Temporary immersion 8 Continuous immersion 	<ul style="list-style-type: none"> Against ingress of water with harmful effects 	
Additional letter (optional)	<ul style="list-style-type: none"> A B C D 		<ul style="list-style-type: none"> Against access to hazardous parts with back of hand Finger Tool Wire
Supplementary letter (optional)	<ul style="list-style-type: none"> H M S W 	<ul style="list-style-type: none"> Supplementary information specific to: High voltage apparatus Motion during water test Stationary during water test Weather conditions 	

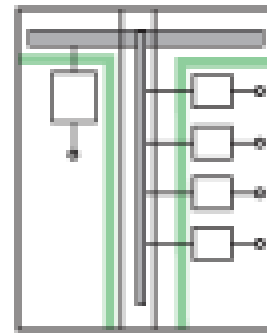
Form Separation of LV Switchgear



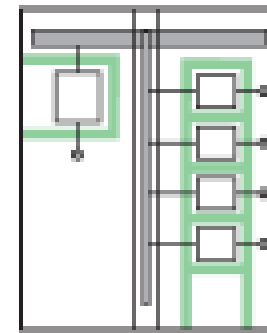
Form 1



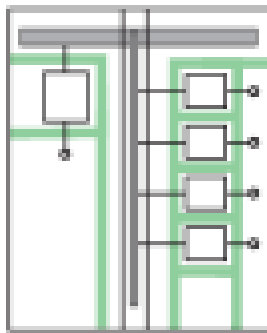
Form 2a



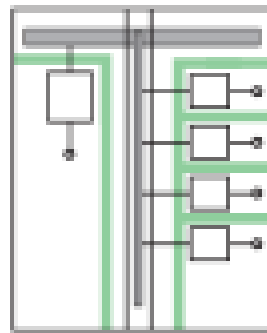
Form 2b



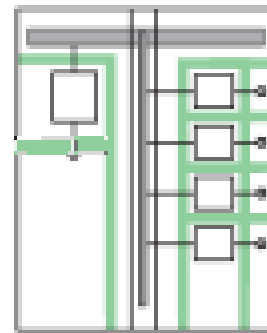
Form 3a



Form 3b



Form 4a



Form 4b

Busbar
Separation

Form Separation of LV Switchgear

Forms 1 and 2



Options in the National Annex of BS EN 61439-2			
Main criteria	Sub-criteria	Form	Type of construction
No separation		Form 1	
Separation of busbars from the functional units.	Terminals for external conductors not separated from busbars.	Form 2a	
	Terminals for external conductors separated from busbars.	Form 2b	Type 1 Busbar separation is achieved by insulated covering, e.g. sleeving, wrapping or coatings. Type 2 Busbar separation is by metallic or non-metallic rigid barriers or partitions.

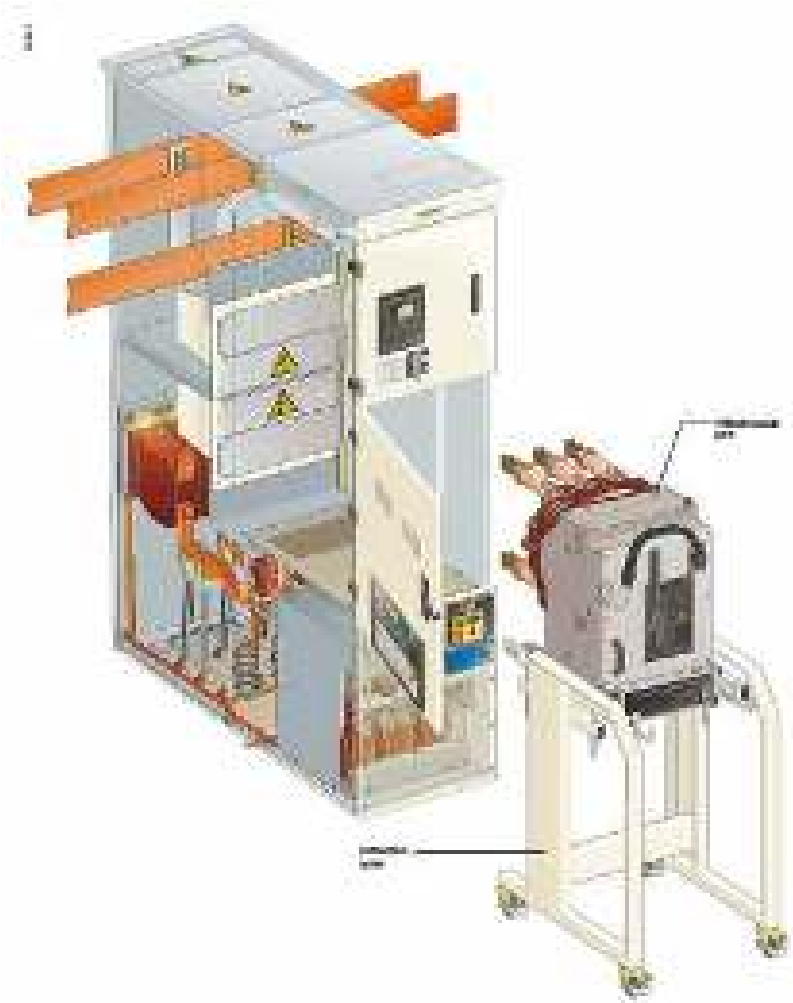
Options in the National Annex of BS EN 61439-2			
Main criteria	Sub-criteria	Form	Type of construction
Separation of busbars from the functional units and separation of all functional units from one another. Separation of the terminals for external conductors from the functional units, but not from each other.	Terminals for external conductors not separated from busbars.	Form 3a	
	Terminals for external conductors separated from busbars.	Form 3b	Type 1 Busbar separation is achieved by insulated covering, e.g. sleeving, wrapping or coatings. Type 2 Busbar separation is by metallic or non-metallic rigid barriers or partitions.

Form 3

Options in the National Annex of BS EN 61439-2

Main criteria	Sub-criteria	Form	Type of construction
Separation of busbars from the functional units and separation of all functional units from one another, including the terminals for external conductors which are an integral part of the functional unit.	Terminals for external conductors in the same compartment as the associated functional unit.	Form 4a	Type 1 Busbar separation is achieved by insulated covering, e.g. sleeving, wrapping or coatings. Cables may be glanded elsewhere.
			Type 2 Busbar separation is by metallic or non-metallic rigid barriers or partitions. Cables may be glanded elsewhere.
			Type 3 Busbar separation is by metallic or non-metallic rigid barriers or partitions. The termination for each functional unit has its own integral glanding facility.
	Terminals for external conductors not in the same compartment as the associated functional unit, but in individual, separate, enclosed protected spaces or compartments.	Form 4b	Type 4 Busbar separation is achieved by insulated covering, e.g. sleeving, wrapping or coatings. Cables may be glanded elsewhere.
			Type 5 Busbar separation is by metallic or non-metallic rigid barriers or partitions. Terminals may be separated by insulated coverings and glanded in common cabling chamber(s).
			Type 6 All separation requirements are by metallic or non-metallic rigid barriers or partitions. Cables are glanded in common cabling chamber(s).
			Type 7 All separation requirements are by metallic or non-metallic rigid barriers or partitions. The termination for each functional unit has its own integral glanding facility.

HV Switchgear Overview



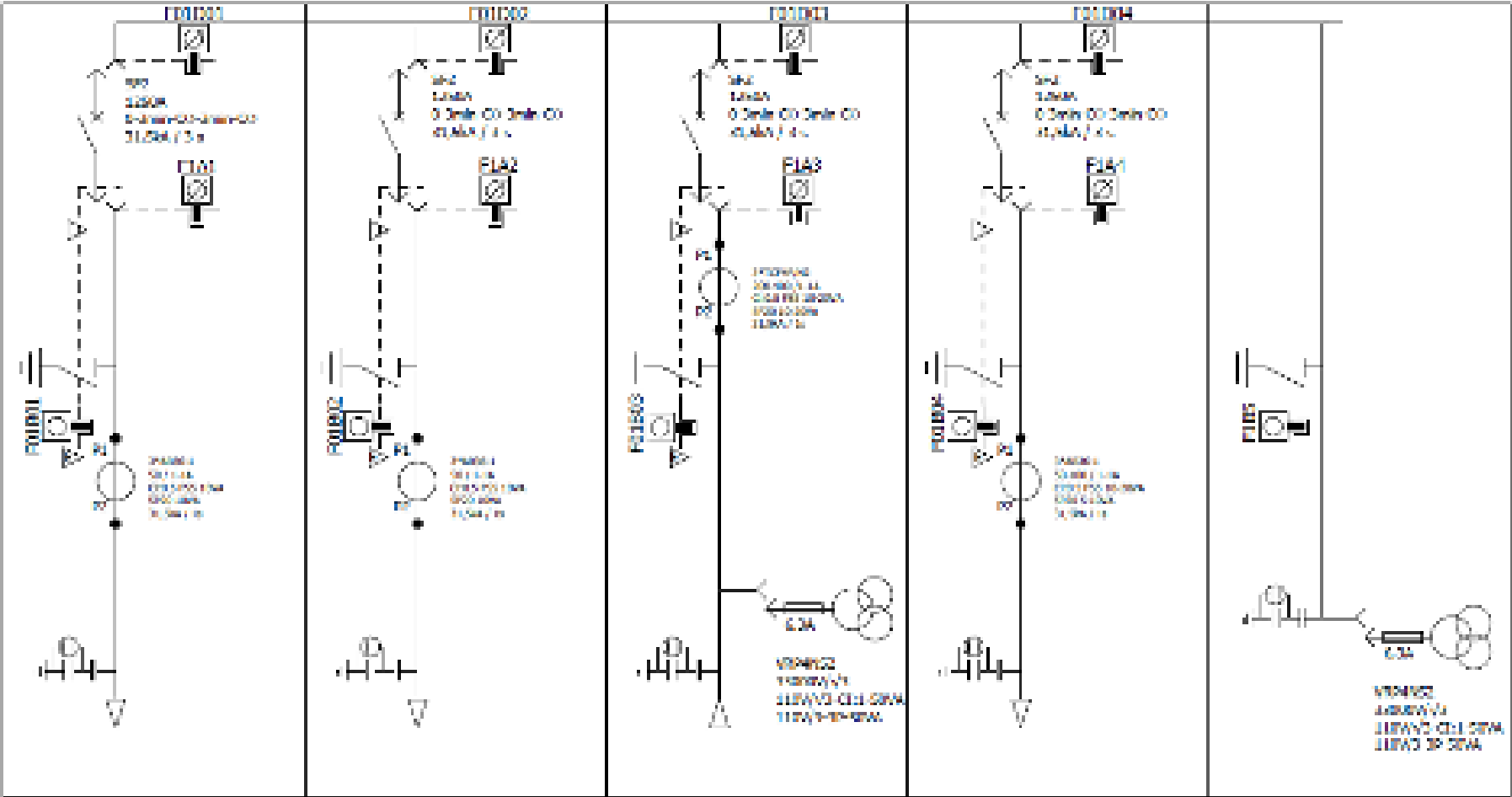
HV Switchgear Overview

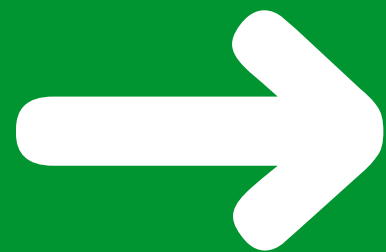


- 1 - Busbars
- 2 - Withdrawable part
- 3 - Current Transformer
- 4 - Cable connections
- 5 - LV control cabinet
- 6 - Sepam or MOCOM relay
- 7 - Voltage transformers



HV Switchgear Overview - SLD





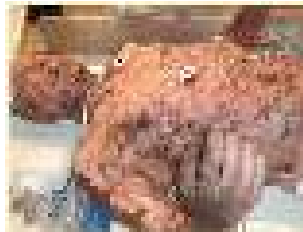
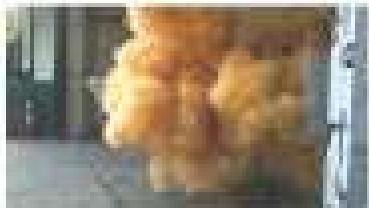
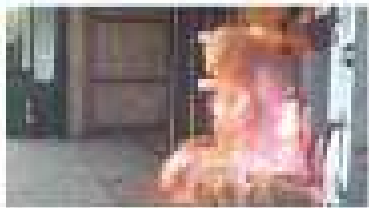
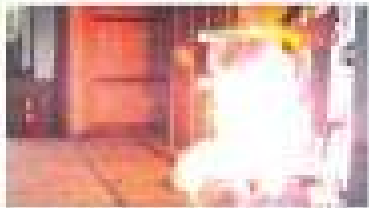
2. Understanding Internal Arc

Effect of Internal Arc

Internal arc faults can be prevented from the initial fault to the progression of the arc. An arc fault can be caused by internal wiring, damaged cables, loose connections, and power wires.



Control Panel
Professional Work
Control Panel



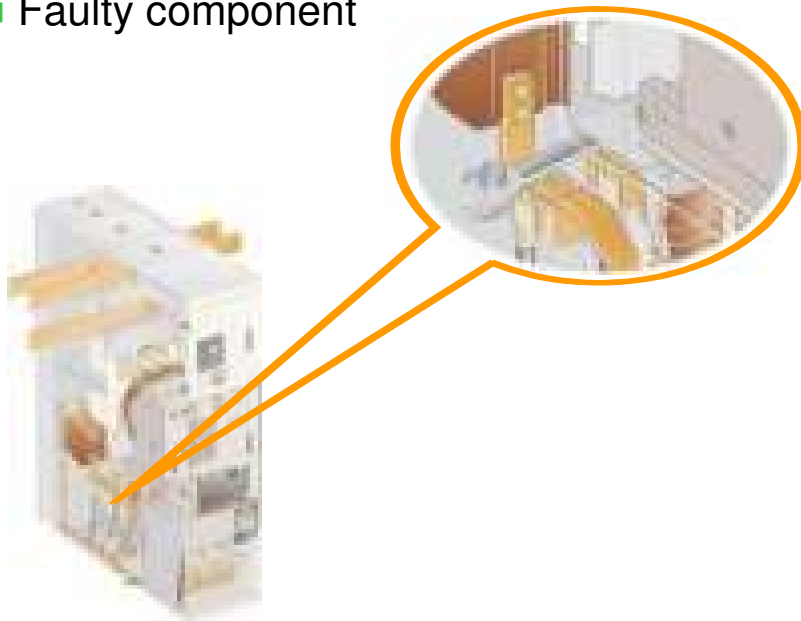
Internal arc withstand is variously named:

- internal arc withstand
 - arc fault containment
 - anti arc Design
-
- Control of the effects of arcing faults within switchgear or other equipment, to protect the operator and (if appropriate) the general public from being injured.
 - Prevention of internal faults through modern design practice, can reduce risk but cannot completely eliminate the possibility of faults.
 - Fast acting protection systems can minimize the effects of arc flash.
 - Elimination of flammable materials would also reduce risk.
 - A 'Vented Cubicle' is NOT necessarily able to withstand internal arc faults.

Origins and consequences of an internal faults

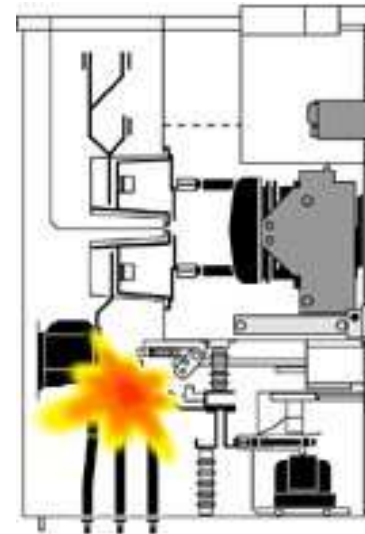
Origins:

- Tools forgotten after maintenance
- Very corrosive atmosphere
- Forced inter-locks
- Overvoltages due to lightning
- Faulty protection system operation
- Faulty component



Consequences:

- Significant overheating (temperature at the core of the arc around 20,000°C)
- Production of hot gases and burning particles
- Increase in pressure
- Deterioration and projection of parts



Other causes the arc flash

Insulation breakthrough in switchgear:

- Not likely but still possible in severe over voltage case
- *Possible even in GIS*

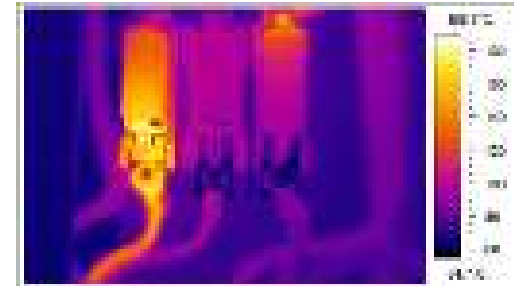
Component failure:

- Cable terminal failures
- CT's and VT's
- Station (auxiliary) transformers
- Contactors, circuit breakers, Circuit breaker connectors

Human errors:

- Falling tools/parts (screws, nuts, etc)
- Use of wrong tools
- Misuse
- Forgotten measurement wires or groundings

Other causes the arc flash



Bad contacts:

- Bad contacts (temperature rise/overload)
- Insufficient tightening moment (Torque)
- Vibration
- Over voltages

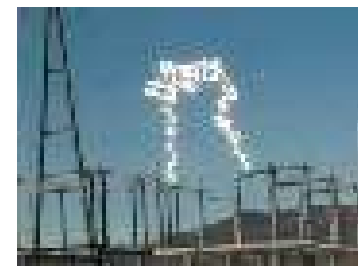
Animals:

- Small animals are often the root cause of arc flash
- Very hard to prevent



There are also arc flash that are out of scope and not to be protected by arc flash relays. Such an arc flash are as:

- Vacuum breaker arc flash
- Arc flash in disconnecter
- Lightning induced arc flash in overhead-lines
- etc...



Arc flash damages on switchgear

- Extremely rapid release of energy in form of heat and pressure
- Arc temperature in range of 20000 °C (three fold surface temperature of the Sun)
- Drastic heat ignites insulation, conductors and metal resulting toxic compounds molten metal blast



Arc flash damages on switchgear

- Switchgear damages are typically very big
- May result to production losses
- May result to personnel damages



Arc flash damages on switchgear



Arc flash damages on switchgear



Arc flash damages on switchgear



Arc Resistant Switchgear in Action



Incident – Breaker Racking



Arc_Flash_racking_breaker.wmv

What Kinds of Injuries Can Result?

Burn Injuries

- First Degree – burns epidermis only
- 2nd Degree – extends deeper; may require skin grafting
- 3rd degree – requires excision, grafting; severe cases may require amputation

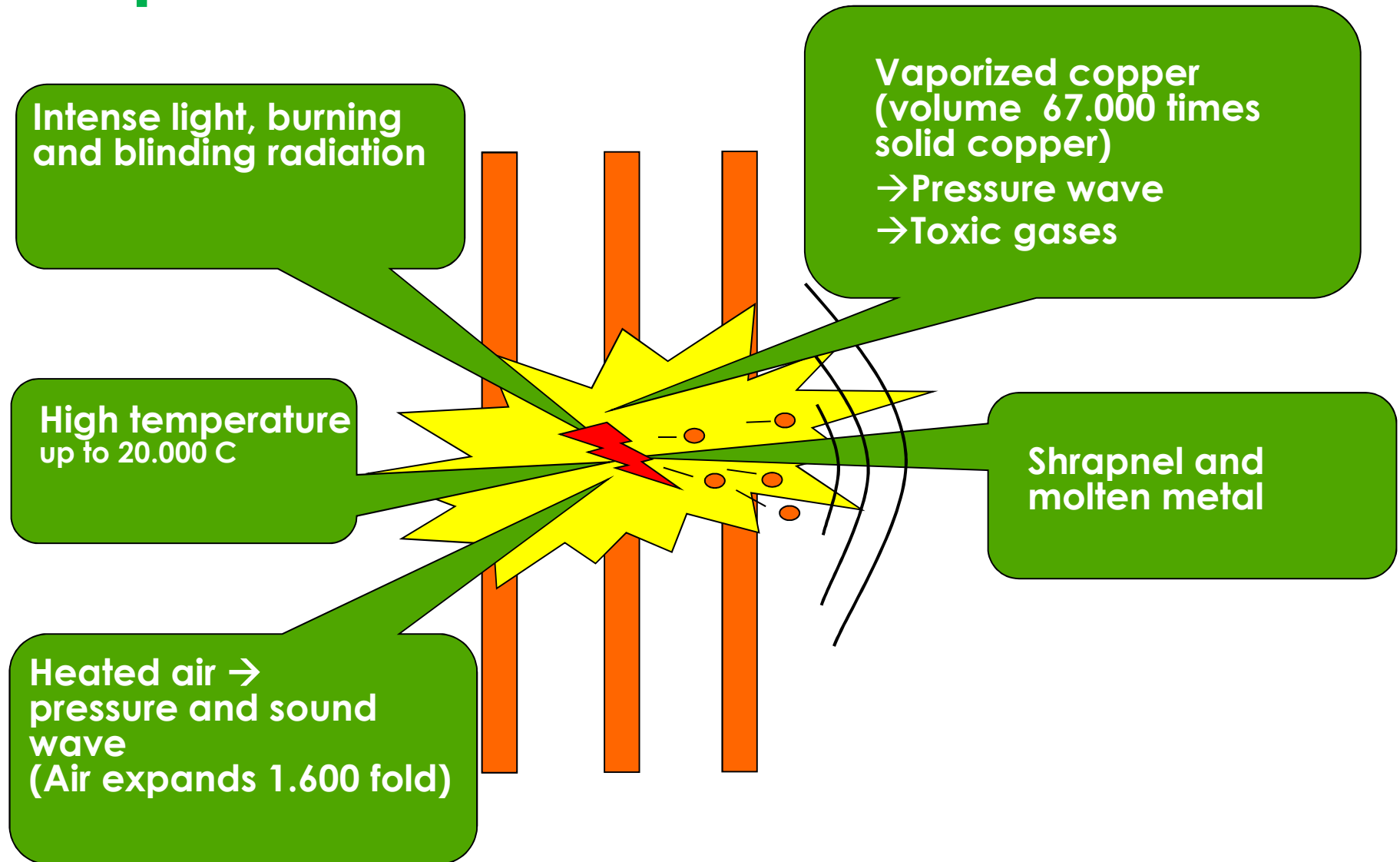
Blast Injuries

- Shrapnel
- Hearing Damage
- Pressure wave

Hierarchy of Risk Control

- Protection (PPE) – least effective
- Administrative Controls – **regulate** risk
- Awareness – **reveal** risk
- Engineering Controls – **manage & control** risk
- Substitution – **replace** risk
- Elimination – **remove** risk

Arc phenomenon



8.103.3 Service continuity of the switchgear

The metal-enclosure is intended to provide a level of protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects. With appropriate sensing and auxiliary control devices, it is also possible to provide a level of protection against failure of insulation to earth (ground).

For each functional unit of switchgear and controlgear the Loss of Service Continuity category (LSC) describes the extent to which other high-voltage compartments and/or functional units may remain energized when a main circuit compartment of this functional unit is opened.

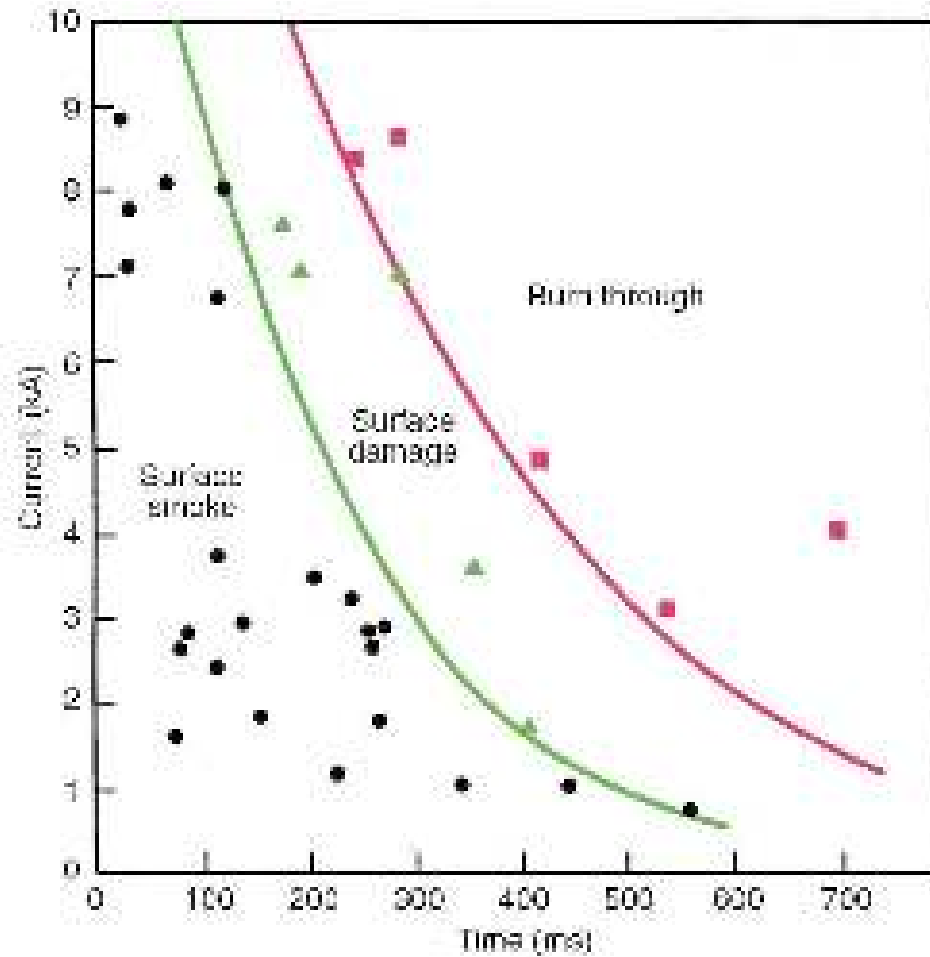
Category LSC1: this form is not intended to provide service continuity during opening of any accessible compartment(s) and may require complete disconnection of the switchgear and controlgear from the system and making dead before such opening.

Category LSC2 family: these forms are intended to allow maximum continuity of service of the network during access to the high-voltage compartments inside the switchgear and controlgear. It means that opening of accessible high-voltage compartments in a functional unit is possible while keeping the other functional units of the same section energised. This implies that at least one busbar can be kept energised. Insertion of a movable partition may be used to achieve this category.

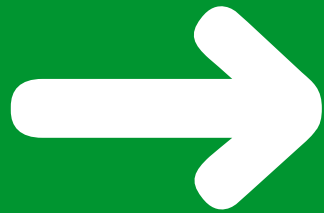
LSC2 as a minimum requires that it is possible to open the connection compartment while keeping the busbar(s) live. There may or may not be other accessible high-voltage compartments (e.g. main switching device).

Arc flash damages on switchgear

Damage to the switchboard as function of current and time



Land, H., Eddins, C., Klimek, J.
Evolution of Arc Fault Protection
Technology at APL,
Johns Hopkins APL Technical
Digest, Volume 25, Number 2, 2004.



3. IEC TR 61641 Guide for testing under conditions of arcing due to Internal Arc

Standards

The main relevant IEC Standards for LV Switchgear

- IEC 61439-1&2: LV Switchgear and Controlgear assemblies
- IEC 60947-2: LV Circuit breakers
- IEC 60947-4: LV Contactors and Motor Starters
- IEC 60529 : Degrees of Protection
- IEC 61921 : LV Capacitor Banks

Technical Report

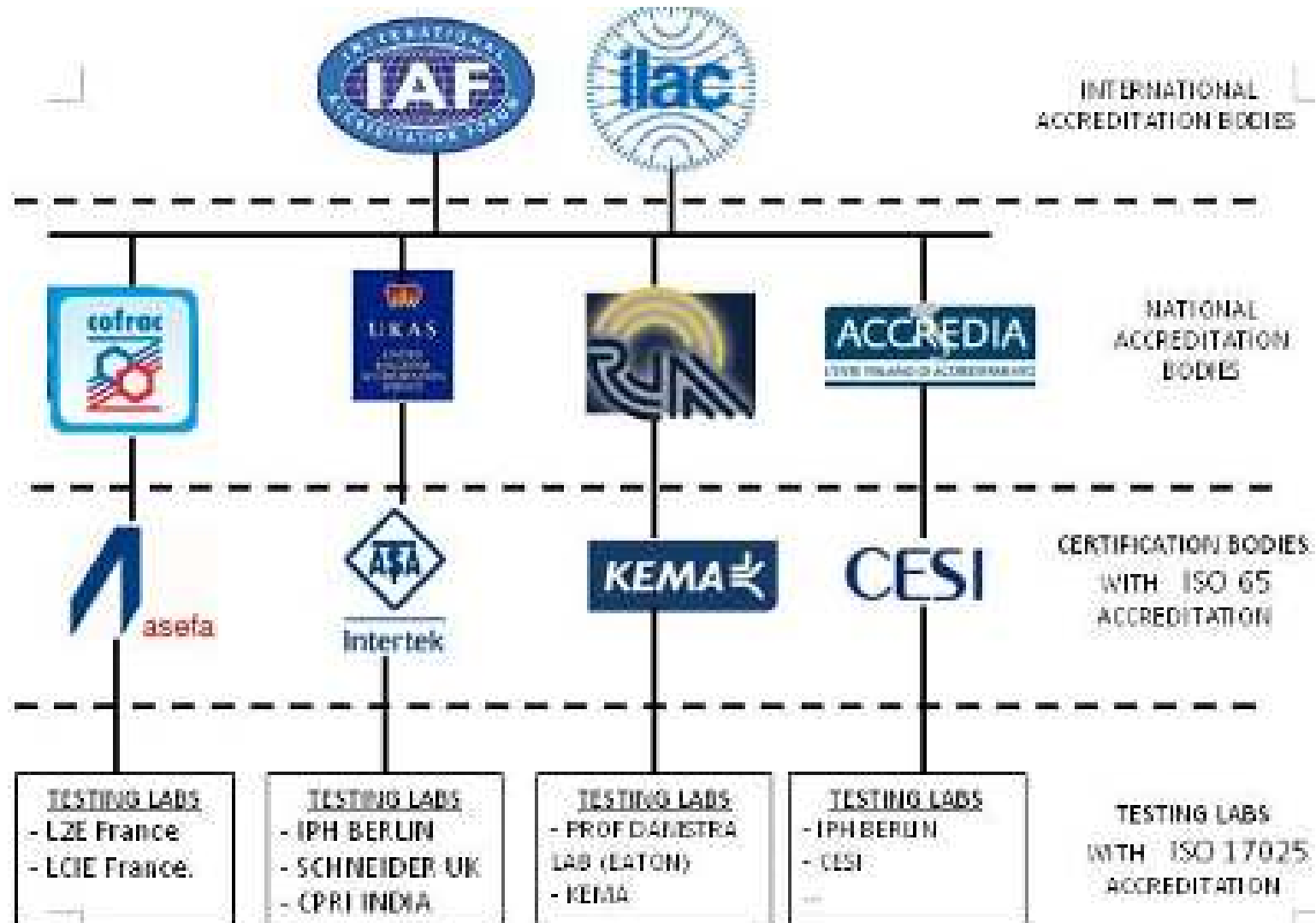
- IEC 61641 : Internal Arc Fault Containment

The main changes

Current IEC 60439-X LV switchgear & controlgear Assemblies	General rules + Power switchgear and controlgear assemblies 60439-1			
	Distribution boards 60439-3	Assemblies for construction sites 60439-4	Assemblies for public networks 60439-5	Busbar trunkings 60439-2
IEC 61439-X LV switchgear & controlgear Assemblies	General rules IEC 61439-1 (Ed.2.0 : 2011)			
	Power switchgear and controlgear assemblies 61439-2 (Ed.2.0 :2011)	Distribution boards 61439-3 (Feb 2012)	Assemblies for construction sites 61439-4 (Nov 2012)	Assemblies for public networks 61439-5 (Nov 2010)

- "*Power Switchgear and Controlgear Assemblies*" are now covered by IEC 61439-2, to be read in conjunction with IEC 61439-1

Certification bodies / Test laboratories



Type Tests and Routine Tests for LV Swgr

Routine tests :

They are intended to detect faults in materials and workmanship and ascertain functioning of the manufactured ASSEMBLY.

● Construction:

- n°1 – degree of protection of enclosures
- n°2 – clearance and creepage distances
- n°3 – protective circuit test
- n°4 – incorporation of built-in components
- n°5 – internal electrical circuits and connections
- n°6 – terminals for external conductors
- n°7 – mechanical operation

● Performance:

- n°8 – dielectric properties
- n°9 – wiring, operational performance and function

11 Type tests on the prototype:

- n°1 Temperature rise limits
- n°2 Dielectric properties
- n°3 Short-circuit withstand
- n°4 Protective circuit effectiveness
- n°5 Clearances and creepage distances
- n°6 Mechanical operation
- n°7 Degree of protection
- n°8 Lifting Test
- n°9 Corrosion resistance
- n°10 Resistance of insulating material to normal heat
- n°11 Resistance of insulating material to abnormal heat

Optional Type Test:

- **Internal Arc Containment**

IEC 61641 TR Internal Arc Containment

The ability of an ASSEMBLY to pass the test according to this technical report is only one aspect.

The skill of the personnel having access to the ASSEMBLY, the personal protective equipment used, the working procedures applied, and the conditions in the location where the ASSEMBLY is installed, are aspects that need to be taken into account.

The Typical Internal Arc Fault result from:

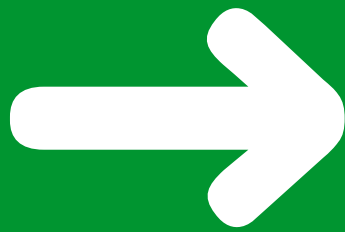
- Conducting materials inadvertently left in ASSEMBLIES during Manufacture, Installation or Maintenance.
- Faults in Materials or workmanship
- Entry of vermin (small animals such as mice, snakes, etc).
- Use of incorrect ASSEMBLY for the application resulting in overheating and subsequently an internal arc fault
- Inappropriate operating condition, or
- Lack of maintenance
- Operator errors

Assessment of the test:

1. Correctly secured doors and covers do not open and remain effectively in place and provide IP 1X of IEC 60529
2. No parts of the ASSEMBLY are ejected which have a mass of more than 60g except those which are dislodged and fall between the ASSEMBLY and the Indicators.
3. Arching does not cause holes to develop in the external parts of the enclosure below 2m at the side declared to be accessible as a result of burning.
4. The Indicators do not ignite
5. The protective circuit for accessible part of the enclosure is still effective in accordance to IEC61439-2
6. The ASSEMBLY is capable of confining the arc to the defined area where it was initiated.
7. After clearing of the fault or after the isolation or disassembly of the affected functionalunits in the defined area, emergency operation of the remaining ASSEMBLY is possible

Table A.1 – Options for classification

Classification Item	Classifications	Comments
<p>ASSEMBLY which is tested according to this technical report</p>	<p>Arcing class A: personnel protection. (Criteria 1 to 5)</p>	<p>Where there is an agreement between the user and the manufacturer less or different criteria may apply.</p>
	<p>Arcing class B: personnel protection plus arcing restricted to a defined area within the ASSEMBLY. (Criteria 1 to 6)</p>	
	<p>Arcing class C: personnel protection plus arcing restricted to a defined area within the ASSEMBLY. Limited operation after the fault is possible. (Criteria 1 to 7)</p>	
	<p>Arcing class I: ASSEMBLY providing protection by means of arc ignition protected zones.</p>	
<p>Access</p>	<p>Restricted (default)</p>	<p>Authorized persons only have access to the ASSEMBLY.</p>
	<p>Unrestricted</p>	<p>The ASSEMBLY can be placed in a location accessible to everyone including ordinary persons</p>
<p>Criteria are defined in 8.7.</p>		



4. Different Designs for LV Switchgear Internal Arc Protection

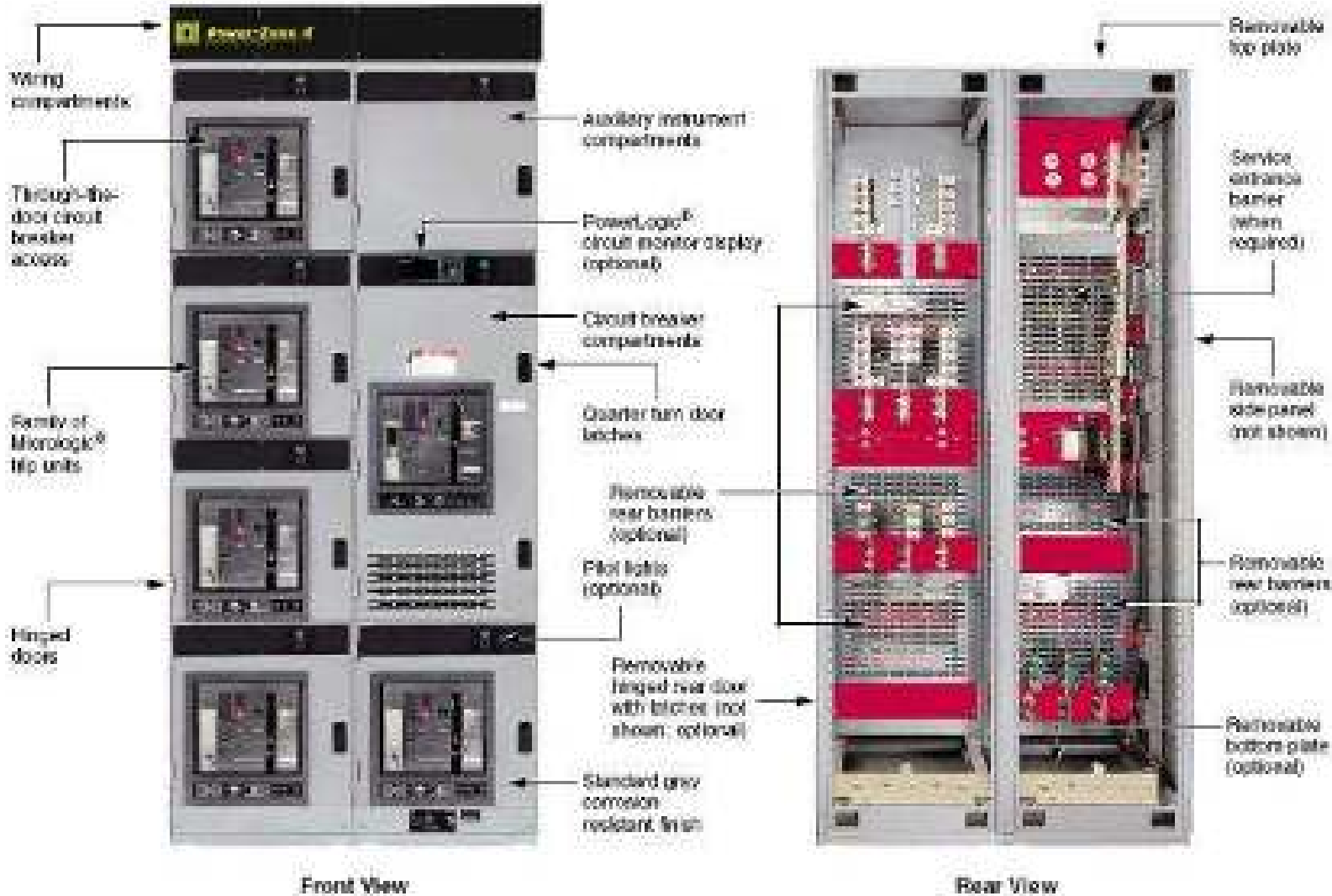
LV Power Switchgear

- Up to 1000Vac
- Drawout circuit breakers
- Grounded metal enclosure
- Ratings:
 - Continuous current
 - Short-time withstand current
 - Short-circuit withstand current
- Unless specifically designated, these ratings are established based on bolted fault currents

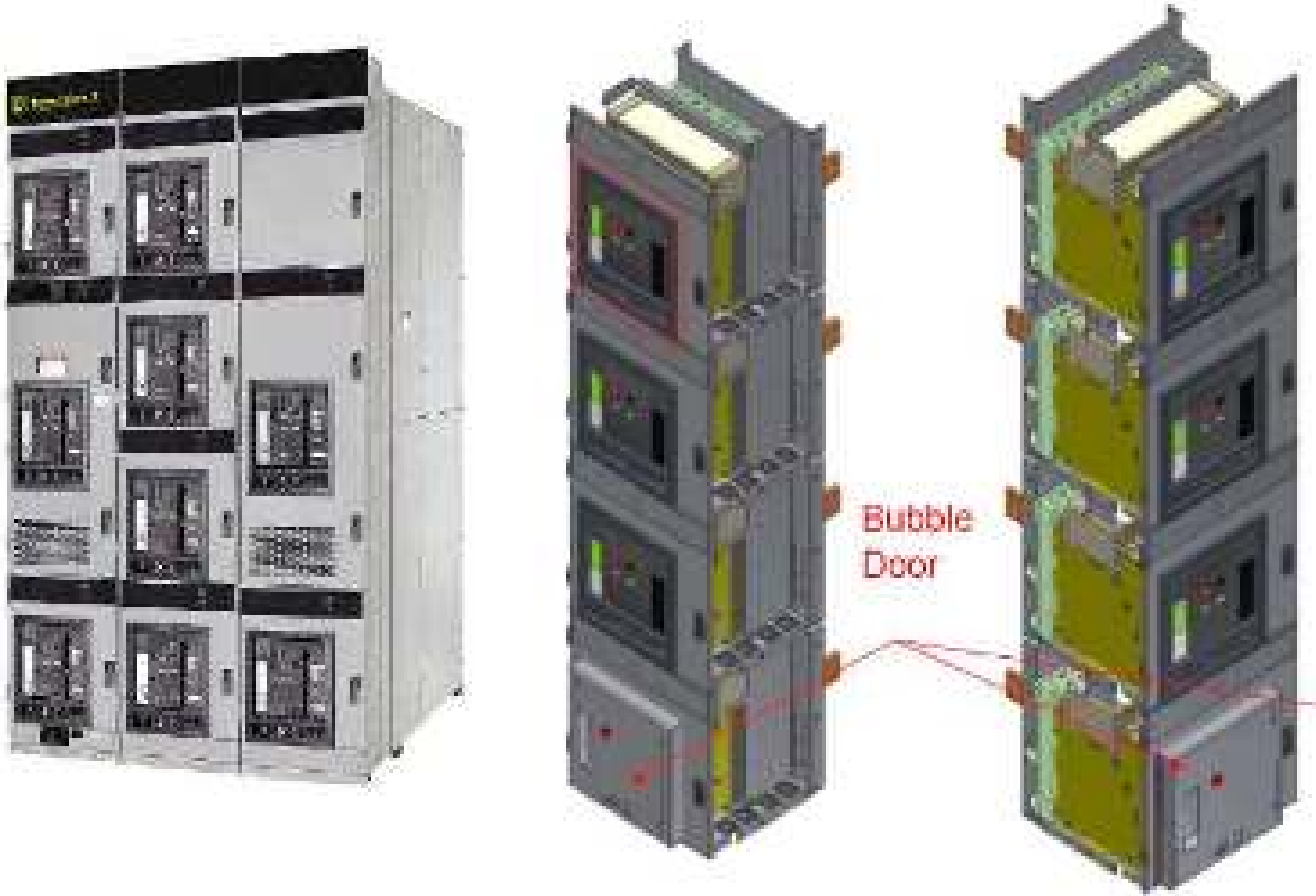
(IEEE C37.20.1)



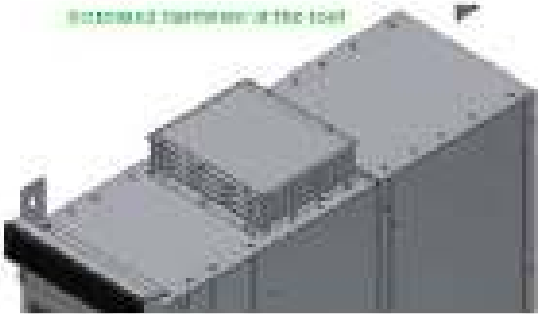
Square D Power-Zone 4 Switchgear



Details are Important!

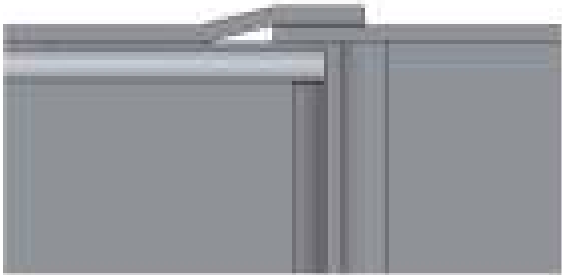


Details are Important!



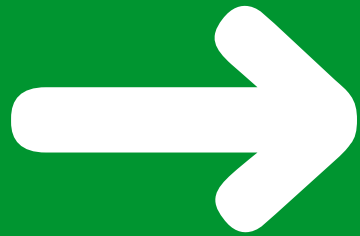
Rotational barrier at the top

Existing concept



New concept





**5. IEC Standard for HV Swgr
on Internal Arc
IEC 622171 - 200**

IEC 62271-1 applies to AC switchgear and controlgear for indoor and /or outdoor installation and for operation at service frequencies up to and including 60Hz and having voltages **above 1000V**. This document applies to all HV switchgear and control gear except as otherwise specified in relevant IEC Standards for particular type of switchgear and controlgear.

IEC 62271-200 applies to AC switchgear and controlgear

High-voltage switchgear and controlgear –

Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

5.101 Internal arc fault

Metal-enclosed switchgear and controlgear that satisfy the requirements of this standard is designed and manufactured, in principle, to prevent the occurrence of internal arc faults. However, where internal arc classification is assigned, the switchgear and controlgear shall be designed to give a defined level of protection of persons in the event of an internal arc, when the switchgear and controlgear is in normal service condition.

6.106 Internal arc test

6.106.1 General

The test is applicable to metal-enclosed switchgear and controlgear, intended to be qualified as IAC classified, covering the event of an arc fault within the enclosure or within components having housings which form part of the enclosure in normal operation conditions. The internal arc test makes allowance for effects acting on all parts of the enclosure, such as internal overpressure, thermal effects of the arc or its roots, the effects of ejected hot gases and glowing particles.

If an internal arc classification is assigned by the manufacturer and verified by type tests according to 6.106, the classification shall be indicated by means of a designation as follows:

- Classification: IAC (Internal Arc Classified)
- Type Accessibility: A, B, C
- Classified sides of the enclosure: F, L, R
- Rated three-phase arc fault values: current [kA] and duration [s]
- Rated single-phase arc fault values (where applicable): current [kA] and duration [s]

Mandatory type tests:

- a) tests to verify the insulation level of the equipment (see 6.2);
- b) tests to prove the temperature rise of any part of the equipment and measurement of the resistance of circuits (see 6.5 and 6.4);
- c) tests to prove the capability of the main and earthing circuits to be subjected to the rated peak and the rated short-time withstand currents (see 6.6);
- d) tests to prove the making and breaking capacity of the included switching devices (see 6.101);
- e) tests to prove the satisfactory operation of the included switching devices and removable parts (see 6.102);
- f) tests to verify the IP protection code (see 6.7.1);
- g) tests to verify auxiliary and control circuits (see 6.10).

Mandatory type tests, where applicable:

- h) tests to verify the protection of the equipment against mechanical impact (see 6.7.2);
- i) tests to verify the protection of persons against dangerous electrical effects (see 6.104);
- j) tests to verify the strength of gas-filled compartments (see 6.103);
- k) tightness tests of gas- or liquid-filled compartments (see 6.8);
- l) tests to assess the effects of arcing due to an internal arc fault (for switchgear and controlgear classification IAC) (see 6.106);
- m) electromagnetic compatibility tests (EMC) (see 6.9);
- n) x-radiation test procedures for vacuum interrupters (see 6.11);
- o) tests to verify the protection of the equipment against external effects due to weather (see 6.105);
- p) dielectric tests on cable testing circuits (see 6.2.101).

Optional type tests (subject to agreement between manufacturer and user):

6.106.2 Test conditions

The test shall be carried out with the switchgear and controlgear in normal operating conditions. This means the position of high-voltage switching devices, connecting and disconnecting withdrawable parts is set to realise the supply circuit according to AA.5.1. All other equipment, for example measuring instruments and monitoring equipment shall be in the position as it is in normal service. If any cover has to be removed and/or any door has to be opened to perform switching operations, the internal arc test shall be carried out with the cover and/or door removed.

Removing or replacing components (for example high-voltage fuses or any other removable component) is not considered to be normal operation, neither to carry out maintenance work.

The test shall be performed in every high-voltage compartment of representative functional units (refer to 6.106.3).

Accessibility – Type A		Accessibility – Type B	
$h \geq 1,9 \text{ m}$	$h < 1,9 \text{ m}$	$h \geq 1,9 \text{ m}$	$h < 1,9 \text{ m}$

IEC 2389/11

Dimensions in millimetres

Key

- S switchgear and controlgear
- h height of switchgear and controlgear
- i_h horizontal indicators
- i_v vertical indicators

Figure AA.3 – Position of the indicators

Criteria to Pass the Test

1. Doors and Covers do not open, no part comes as far as the indicator or Wall
2. No fragmentation of enclosure occurs, no ejection of fragments or of other parts of the Swgr of an individual of 60 grams.
3. Arching does not cause holes by burning through in the classified sides of up to 2000mm
4. Indicators do not ignite due to the effect of the hot gases or burning liquid.
5. The enclosure remains connected to its earthing point.

Test Criteria in IEEE C37.20.7

C37.20.7 is a performance-based standard

- Does not define or mandate design features
- Sets forth criteria that must be met in order to obtain the classification

In short, equipment is submitted to internal arcing faults

- Initiated by a “fuse wire”
 - LV – 2.6mm diameter (#10 AWG)
 - MV – 0.5mm diameter (#24 AWG)
- Current = rated short-time current of the equipment
- Defined duration – preferred value = 0.5 seconds

Equipment tested in “service” condition – e.g., configuration is supposed to mimic, as closely as possible, actual field conditions

Protective devices are allowed to help achieve the AR rating

- Equipment nameplate must be marked to indicate that they are required

Performance Criteria in IEEE C37.20.7

Criterion 1: properly latched or secured doors, covers, and so on, do not open.

Criterion 2: No fragmentation of the enclosure

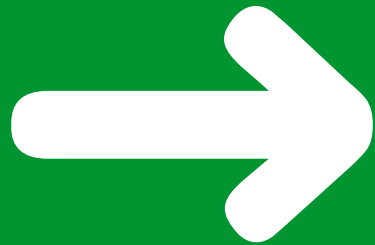
- Ejection of some small parts above 2m height is allowed...

Criterion 3: No burn-through

Criterion 4: No cotton indicators ignite

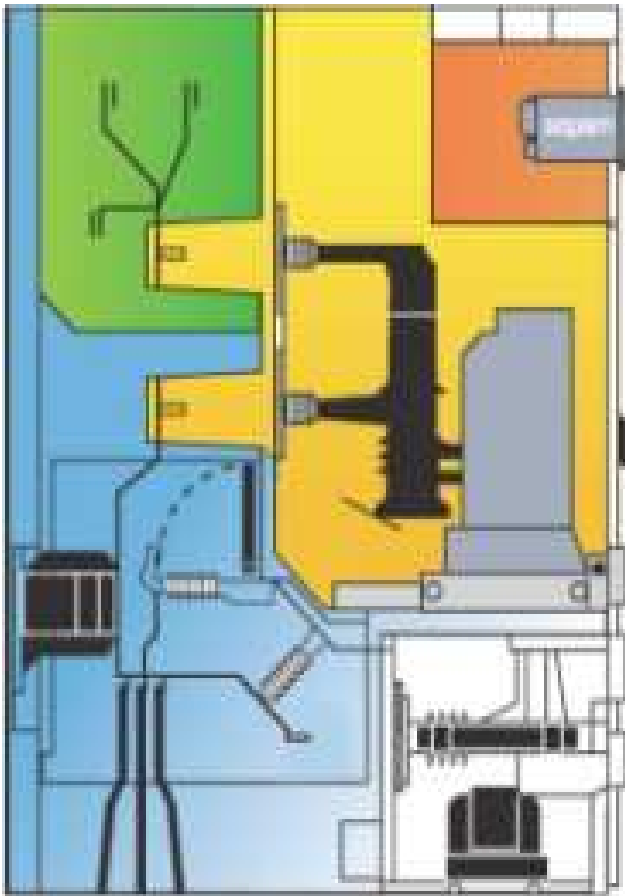
- They are placed outside the gear and near gas exhaust means

Criterion 5: All grounding connections remain effective



6. Designs on Internal Arc Protection for HV Switchgears

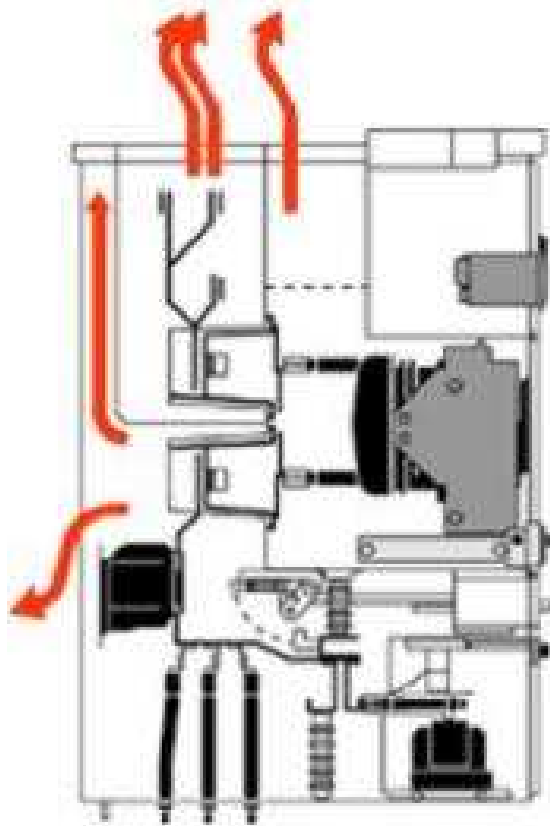
Partitioning & Nature of barrier



Compartments : description of design and function

- The manufacturer defines the number & content of compartments
- Each compartment is described as:
 - design:
 - fixed
 - removable
 - withdrawable
 - extractible
 - accessibility:
 - interlocked-controlled
 - procedure based
 - tools based
 - none-accessible

HV Switchgear Solution Against Internal Arcing

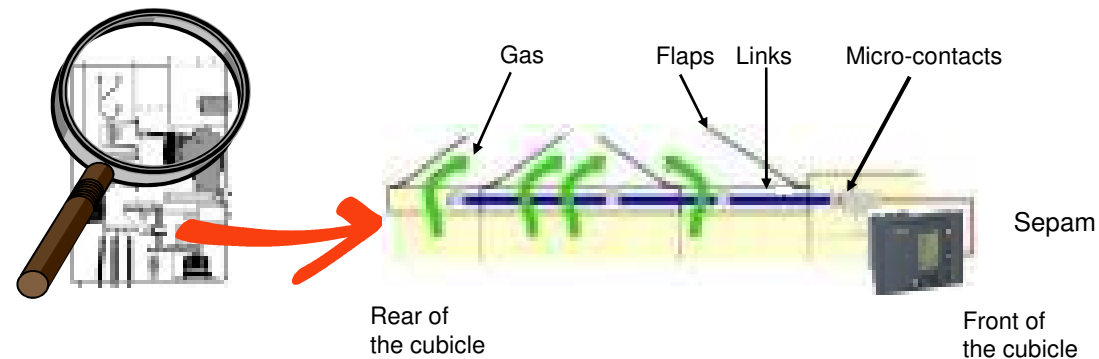


- Must resist to mechanical and thermal stresses
- Must protect the operator against any risk resulting from the devastating effects of possible internal arcing
- The cubicle design allows for arcing effects to be contained (internal suppression, mechanical and thermal stress):
 - choice of non-flammable materials
 - channelling of hot gases

HV Switchgear Solution Against Internal Arcing

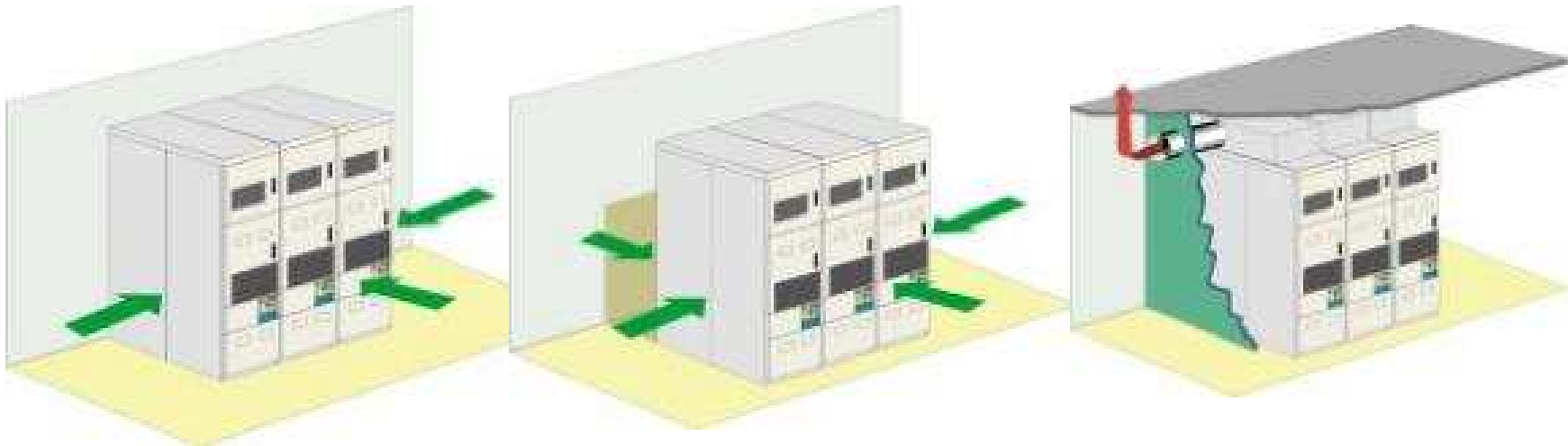
In addition to the internal arc version, cubicle can be equipped with solutions to limit internal arcing

- Limits the duration of the fault
- Mechanical Internal arc detector on the cubicle:
 - Swgr associated with a Sepam relay eliminates the fault in less than 140 ms



HV Switchgear Solution Against Internal Arcing

Installation example



Switchboard against a wall.
AFL anti-arcing protection

Switchboard in the middle
of the room.
AFLR anti-arcing
protection
(access around the back
of the switchboard)

Switchboard in a room
with a ceiling height of less
than 4 meter

Switchgear, Arc-Resistant. Equipment designed to withstand the effects of an internal arcing fault and that directs the internally released energy away from the employee.

Only switchgear specifically identified as being arc resistant provides protection from an internal arcing fault when the equipment is closed and operating normally. If doors and covers (including fasteners) are not completely closed, employees are exposed to the hazards associated with an arcing fault just as if no arc-resistant rating existed. Exhibit 110.14 shows an examples of arc-resistant switchgear and metal-clad switchgear.

EXHIBIT 100.14



An exterior comparison of arc-resistant switchgear (left) and metal-clad switchgear (right). (Courtesy of Schneider Electric)

Exhaust Plenum

- **Plenum Required if:**

- Ceiling less than 192" (4.87m)
- Power Zone Center Application
- Exhaust needed from equipment room
- 50kA rating (optional use-arc shield)

Arc Exhausting Systems

Table 4: Minimum Required Ceiling Height

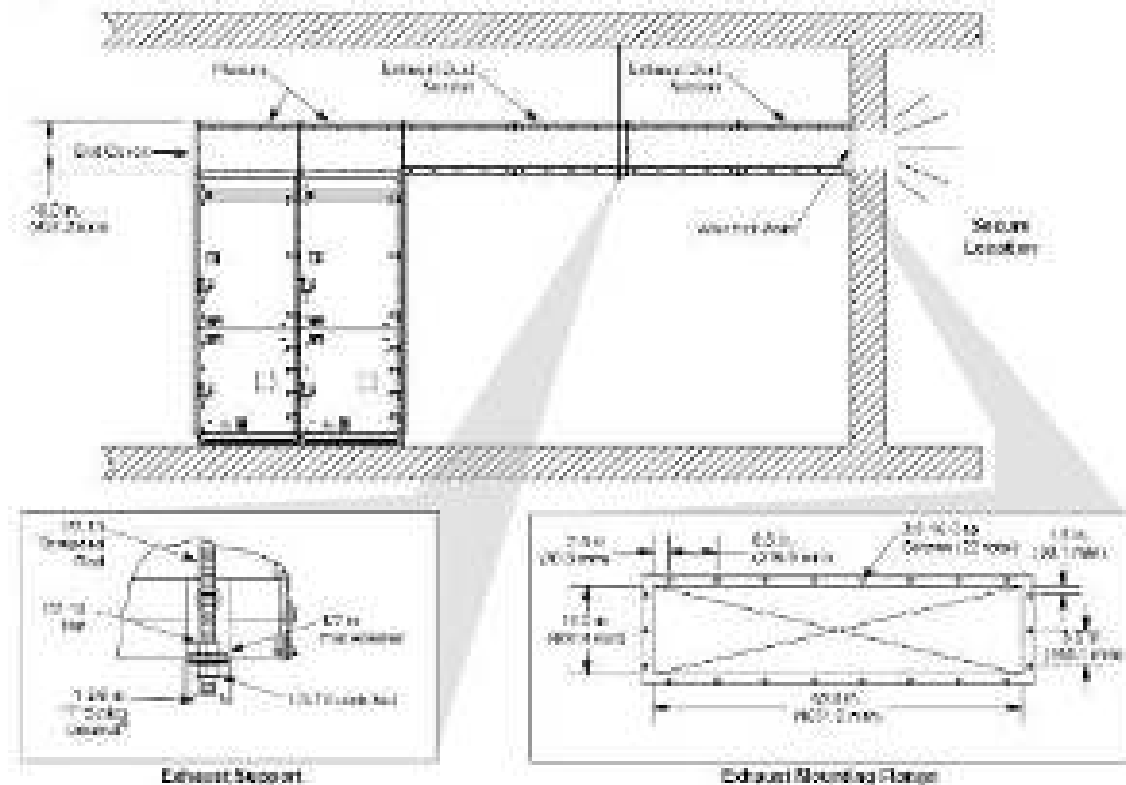
Overhead application	192 in. (4880 mm)
Under application	170 in. (4260 mm)
Use of arc shield/curtain	192 in. (4880 mm)

Plenum Assembly

- Full overhead, industry explosive, and surrounding systems are required
- A plenum for isolating and back exhaust to a forced, safe location, and
- An arc shield for protecting the backhand or protection from hazardous arc flash gases and debris overflowing the top exhaust ports.

The plenum is mounted on the top of each compartment to help isolate and contain energy in the event of an electrical fault. The exhaust must always be directed to a secure location.

Figure 55: Typical Indoor Plenum Application



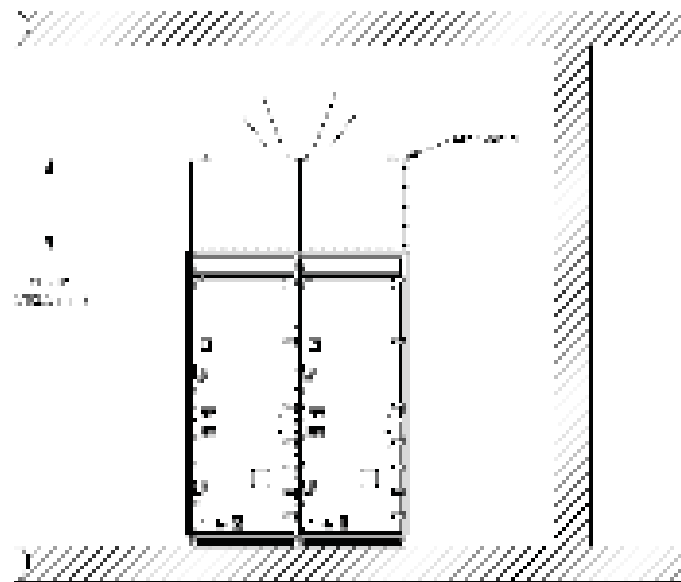
Alternative – “Arc Shield”

- Arc Shield Required if:
 - 50kA rating (optional use-plenum)
 - Increase likelihood of protection for front, rear, & sides of equipment

Arc Shield Assembly

The Arc Shield is designed to contain an arc flash event at the split and seal an arc flash event. It is designed to increase the likelihood of protection of the front, rear, and sides of the equipment.

Figure 28 Typical Arc Shield Application



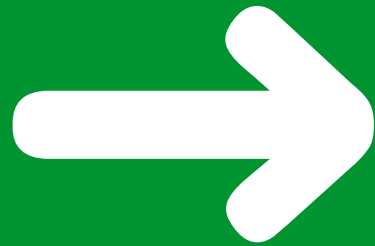
The Arc Shield is designed to contain an arc flash event at the split and seal an arc flash event. It is designed to increase the likelihood of protection of the front, rear, and sides of the equipment.

- Ceiling height (over door) = 102 in. (2610 mm)
- Depth (side view of equipment) = 48 in. (1219 mm)
- Height of equipment = 72 in. (1829 mm)

As shown in Figure 28, the Arc Shield is designed to contain an arc flash event at the split and seal an arc flash event. It is designed to increase the likelihood of protection of the front, rear, and sides of the equipment.

Equipment Nameplate

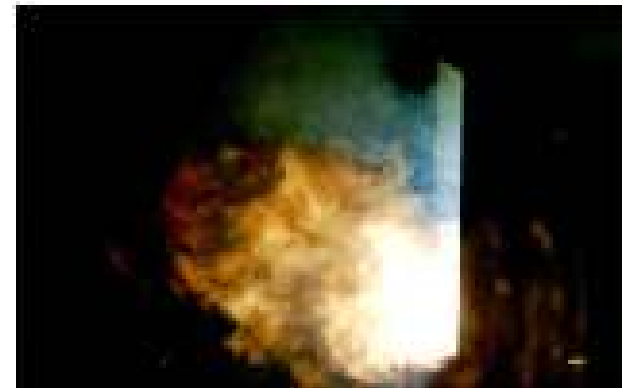
- Must specifically indicate arc-resistant ratings:
 - Accessibility type
 - Internal arcing short-circuit current
 - Arcing duration
 - Type of protective device (when applicable)
 - Rated maximum clearing time for protective device (when applicable)
- When fuses or fast-acting devices are used, the “DEVICE LIMITED” must appear along with the part # under the “arcing duration”



7. Arc Flash Protection

Arcing Faults Vs Short Circuits

- **Short Circuit** – A bolted short circuit...picked-up by Circuit breakers and interrupted in few milli-seconds.
- **Internal Arc** – Arcing between phases creates a low-current, high-impedance path in open air. ...generally the low current value cannot be picked-up by Circuit breakers....results in ionizing the air around it causing tremendous increase in pressure.
- **Flash hazard** – A dangerous condition associated with the release of energy caused by an electric arc.
- In worst cases, a very violent event
 - Significant heat energy released
 - Significant pressure wave – an explosive event!



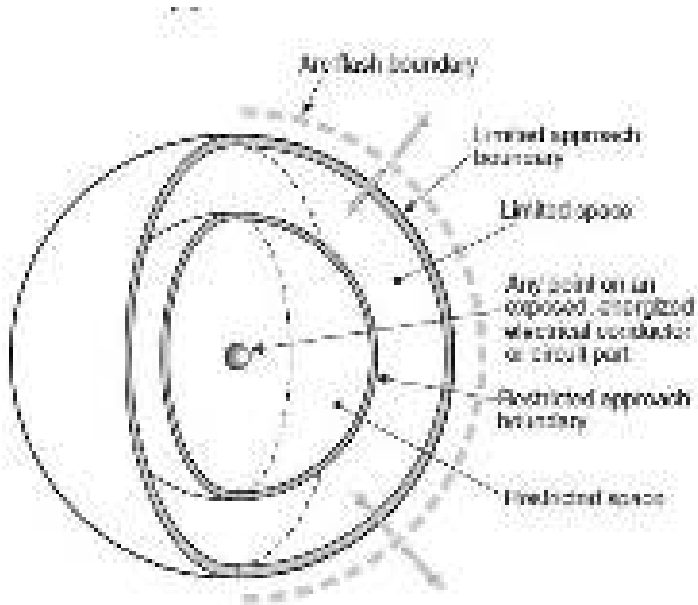


FIGURE 4.1.3.3 Limits of Approach.

$$E = 2.142 \times 10^6 V I_{bf} \left(\frac{t}{D^2} \right)$$

where¹⁷

- E is incident energy (J/cm²)
- V is system voltage (kV)
- t is arcing time (seconds)
- D is distance from possible arc point to person (mm)
- I_{bf} is bolted fault current

Term	Description
Arc Flash Hazard	A dangerous condition associated with the release of energy caused by an electric arc
Arcing Fault Current	A fault current flowing through an electrical arc plasma, also called arc fault current and arc current
Bolted Fault Current	A short circuit or electrical contact between two conductors at different potentials in which the impedance or resistance between the conductors is essentially zero
Flash Hazard Analysis	A method to determine the risk of personal injury as a result of exposure to incident energy from an electric Arc Flash.
Incident Energy	The amount of energy impressed on surface, a certain distance from the source, generated during an electrical arc event. Incident energy is measured in Joules per centimetre squared (J/cm ²) or Calories per centimetre squared (cal./cm ²)
Protection Boundaries	Boundaries relating to electrical safety when working on energized equipment. Only qualified personnel can enter these boundaries which requires appropriate PPE
Arc Flash Boundary	The flash protection boundary is the distance from the arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault falling on the surface of the skin is 1.2cal/cm ² . An exposure to 1.2cal/cm ² would normally result in a curable second-degree burn. Within this boundary workers are required to wear protective clothing like fire resistant (FR) shirts and pants, and other equipment to cover various parts of the body. This distance may vary from equipment to equipment since it is a function of the available fault current of the system at that point, the voltage and the tripping characteristics of the upstream protective device as well as some other parameters.

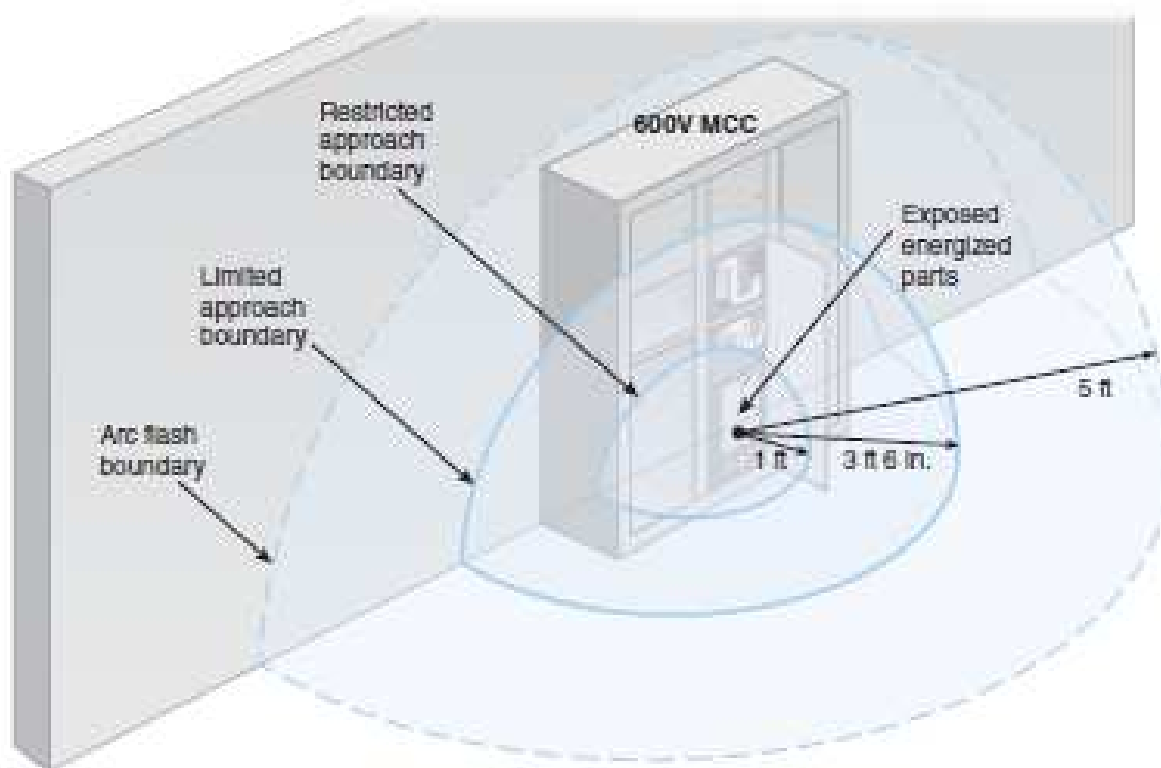


EXHIBIT 130.4

Three approach boundary distances for a 600-volt MCC

N Table 130.4(D)(a) Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems

(1) Nominal System Voltage Range, Phase to Phase ^a	(2) Limited Approach Boundary ^b		(4) Restricted Approach Boundary ^b ; Includes Inadvertent Movement Adder
	Exposed Movable Conductor ^c	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–150 V ^d	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
151 V–750 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
751 V–15 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–36 kV	3.0 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.8 m (2 ft 9 in.)
36.1 kV–46 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
46.1 kV–72.5 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
138 kV–145 kV	3.4 m (11 ft 0 in.)	3.0 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
161 kV–169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.3 m (4 ft 3 in.)
230 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	1.7 m (5 ft 8 in.)
345 kV–362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	2.8 m (9 ft 2 in.)
500 kV–550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	3.6 m (11 ft 8 in.)
765 kV–800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	4.9 m (15 ft 11 in.)

Notes:

Source: NFPA 70E 2018


A Table 130.4(D)(b) Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems

(1) Nominal Potential Difference	(2) Limited Approach Boundary		(4) Restricted Approach Boundary; Includes Inadvertent Movement Adder
	(3) Exposed Movable Conductor*	(3) Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	0.9 m (3 ft 0 in.)	1.0 m (3 ft 0 in.)	Avoid contact
301 V–1 kV	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.5 m (1 ft 0 in.)
1.1 kV–5 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.5 m (1 ft 5 in.)
5 kV–15 kV	3.0 m (10 ft 0 in.)	1.8 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–45 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
45.1 kV–75 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 0 in.)
75.1 kV–150 kV	3.3 m (10 ft 9 in.)	3.0 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
150.1 kV–250 kV	3.5 m (11 ft 6 in.)	3.5 m (11 ft 6 in.)	1.5 m (5 ft 0 in.)
250.1 kV–500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV–800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.

*Exposed movable conductor describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

Source: NFPA 70E 2018

 WARNING	
415 VAC	Arc Flash and Shock Hazard
3.00 m (Shock) Limited approach (Qualified Persons Only) 30 cm (Shock) Restricted approach (PPE Required) (Shock) (PPE Required) 1.13 m (Flash) Arc flash boundary (PPE Required) 455 mm (Flash) Working distance (PPE Required)	
PPE Level 2 PPE Required (7.46 cal/cm ²)	
Eye and Head	Safety glasses or safety goggles, ER hard hat (class G or E), Arc-rated faceshield and arc-rated balaclava or arc flash suit hood (AR), hearing protection
Body	8 cal/sq cm, Cotton underwear, T-shirt or trouser; AR long-sleeve shirt and AR pants or AR coverall or arc flash suit; AR jacket, parka, rainwear or hard hat liner (AN)
Hand and Arm	Heavy-duty leather gloves or rubber insulating gloves with leather protection
Foot	Leather shoes (flash), Dielectric shoes or insulation mat (step and touch potential)
Equipment Name: Arc Flash Analysis by:	33425WGR (8/10/2018)


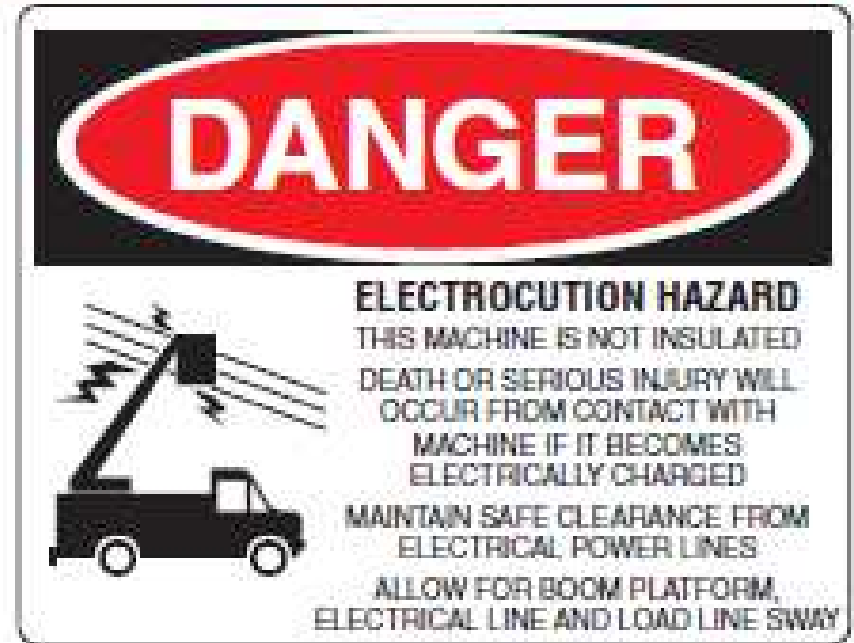
 DANGER	
415 VAC	Arc Flash and Shock Hazard
3.00 m (Shock) Limited approach (Qualified Persons Only) 30 cm (Shock) Restricted approach (PPE Required) (Shock) (PPE Required) 2.84 m (Flash) Arc flash boundary (PPE Required) 455 mm (Flash) Working distance (PPE Required)	
Prohibited Entry	
Arc flash incident energy exceeds 40 cal/cm ²	
Equipment Name: Arc Flash Analysis by:	33425WGR (8/10/2018)

Figure 4-1 – Warning Label (Sample)



(a)



(b)

(a) A crane operating in close proximity to energized overhead power lines. (Courtesy of FEMA, photo by George Armstrong) (b) Signage warning against contact with overhead power lines.

TABLE 130.7.5.5(a) Air-Flash PPE Category for Alternating Current (ac) Systems

Equipment	Air-Flash PPE Category	Air-Flash Boundary
Panelboards or other equipment rated 240 volts and below Parameters: Maximum of 25 kA available fault current, maximum of 0.01 sec (12 cycles) fault clearing time, minimum working distance 457 mm (18 in.)	1	480 mm (19 in.)
Panelboards or other equipment rated greater than 240 volts and up to 600 volts Parameters: Maximum of 25 kA available fault current, maximum of 0.01 sec (12 cycles) fault clearing time, minimum working distance 457 mm (18 in.)	2	900 mm (35 in.)
600-volt class motor control centers (MCCs) Parameters: Maximum of 65 kA available fault current, maximum of 0.01 sec (12 cycles) fault clearing time, minimum working distance 457 mm (18 in.)	3	1.5 m (5 ft)
600-volt class motor control centers (MCCs) Parameters: Maximum of 45 kA available fault current, maximum of 0.01 sec (12 cycles) fault clearing time, minimum working distance 457 mm (18 in.)	4	4.3 m (14 ft)
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards Parameters: Maximum of 35 kA available fault current, maximum of up to 0.5 sec (30 cycles) fault clearing time, minimum working distance 457 mm (18 in.)	4	4 m (13 ft)
Other 600-volt class (377 volts through 600 volts, industrial equipment) Parameters: Maximum of 65 kA available fault current, maximum of 0.01 sec (12 cycles) fault clearing time, minimum working distance 457 mm (18 in.)	3	1.5 m (5 ft)
MVA (2 closed-contact) motor starters, 2.5 kV through 7.2 kV Parameters: Maximum of 35 kA available fault current, maximum of up to 0.24 sec (15 cycles) fault clearing time, minimum working distance 900 mm (36 in.)	4	1.2 m (4 ft)
Motor-class switchgear, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current, maximum of up to 0.24 sec (15 cycles) fault clearing time, minimum working distance 900 mm (36 in.)	4	1.2 m (4 ft)
Any resistant volt classed 1 kV through 15 kV (1 kV clearing times of less than 0.5 sec (30 cycles) with an available fault current not to exceed the arc-resistance rating of the equipment), and metal-enclosed interrupter switchgear, fused or unfused of air-resistant-type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current, maximum of up to 0.24 sec (15 cycles) fault clearing time, minimum working distance 900 mm (36 in.)	4 (above) or 4 (below)	1.2 m (4 ft) or 4.3 m (14 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current, maximum of up to 0.24 sec (15 cycles) fault clearing time, minimum working distance 900 mm (36 in.)	4	1.2 m (4 ft)

Note: For equipment rated 600 volts and below and protected by upstream circuit-breaking fuses or current-limiting circuit breakers rated at 200 amperes or less, the air-flash PPE category can be reduced by one number (but not below an air-flash PPE category 1).

For additional details, see [Table 130.7.5.5\(b\)](#). The following are typical fault clearing times of over-current protective devices:

- (1) 25-cycle fault clearing time is typical for most of the air-resistant type circuit breakers used in the current-limiting zone.
- (2) 1.5-cycle fault clearing time is typical for molded case circuit breakers rated less than 600 volts with an instantaneous tripping trip.
- (3) 30-cycle fault clearing time is typical for non-instantaneous-trip breakers rated less than 600 volts with an instantaneous-tripping trip or a 30-cycle trip.
- (4) 0.01 sec (12 cycles) clearing time is typical for air-resistant type circuit breakers rated 1 kV and below with an instantaneous-tripping trip or a 30-cycle trip.
- (5) 0.5-sec fault clearing time is typical for most of the air-resistant type circuit breakers rated 1 kV and above with an instantaneous-tripping trip or a 30-cycle trip.

TABLE 130.7.5.5(b) Air-Flash PPE Category with Modifications

What is arc flash protection - PPE

- Arc flash protection can be understood in many ways



Does this protect user in case of arc flash hazard? Yes, maybe, no.

Use of PPE gives protection against heat and flying objects but PPE may not give protection against toxic gases, pressure shock, high sound pressure, falling or slipping, etc...

Does PPE protect switchgear against damages? No

Note: This table is not applicable to installations not started using the required minimum system arc rating. For the full PPE clothing requirements for the initial energy analysis method, see 130.702 and 130.703 (through 130.714).

Arc-Rating PPE Category	PPE
1	<p>Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm² (16.7 J/cm²)</p> <p>Arc-rated long-sleeve shirt and pants or coveralls or suit</p> <p>Arc-rated hood or face shield and hood</p> <p>Arc-rated arc face, pants, trousers, or hard hat liner (AR)</p> <p>Protective Equipment</p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SR)</p> <p>Hearing protection for small events¹</p> <p>Heavy-duty leather gloves²</p> <p>Leather footwear (AR)</p>
2	<p>Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm² (33.5 J/cm²)</p> <p>Arc-rated long-sleeve shirt and pants or coveralls or suit</p> <p>Arc-rated hood or face shield or arc-rated face shield³ and arc-rated trousers</p> <p>Arc-rated arc face, pants, trousers, or hard hat liner (AR)</p> <p>Protective Equipment</p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SR)</p> <p>Hearing protection for small events¹</p> <p>Heavy-duty leather gloves²</p> <p>Leather footwear</p>
3	<p>Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm² (104.2 J/cm²)</p> <p>Arc-rated long-sleeve shirt (AR)</p> <p>Arc-rated pants (AR)</p> <p>Arc-rated coveralls (AR)</p> <p>Arc-rated arc face and jacket (AR)</p> <p>Arc-rated arc face and pants (AR)</p> <p>Arc-rated arc face and hood</p> <p>Arc-rated (AR)⁴</p> <p>Arc-rated arc face, pants, trousers, or hard hat liner (AR)</p> <p>Protective Equipment</p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SR)</p> <p>Hearing protection for small events¹</p> <p>Leather footwear</p>

TABLE 130.70C (11)(e) – Continued

Arc-Rating PPE Category	PPE
4	<p>Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm² (167.5 J/cm²)</p> <p>Arc-rated long-sleeve shirt (AR)</p> <p>Arc-rated pants (AR)</p> <p>Arc-rated coveralls (AR)</p> <p>Arc-rated arc face and jacket (AR)</p> <p>Arc-rated arc face and pants (AR)</p> <p>Arc-rated arc face and hood</p> <p>Arc-rated gloves⁵</p> <p>Arc-rated jacket, pants, trousers, or hard hat liner (AR)</p> <p>Protective Equipment</p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SR)</p> <p>Hearing protection for small events¹</p> <p>Leather footwear</p>

AR: Arc-rated (optional); AR: Arc-rated; SR: Selected required.

¹One rating is defined in [Article 100](#).

²These gloves are to have wrap-around gauntlet to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc face and hood is required to be worn.

³Other types of hearing protection are permitted to be used in lieu of or in addition to earplugs or earmuffs, provided they are worn under an arc-rated arc face and hood.

⁴Unless insulating gloves with leather protection are used, additional leather or arc-rated gloves are not required.

⁵The combination of rubber insulating gloves with leather protection satisfies the arc face protection requirement.

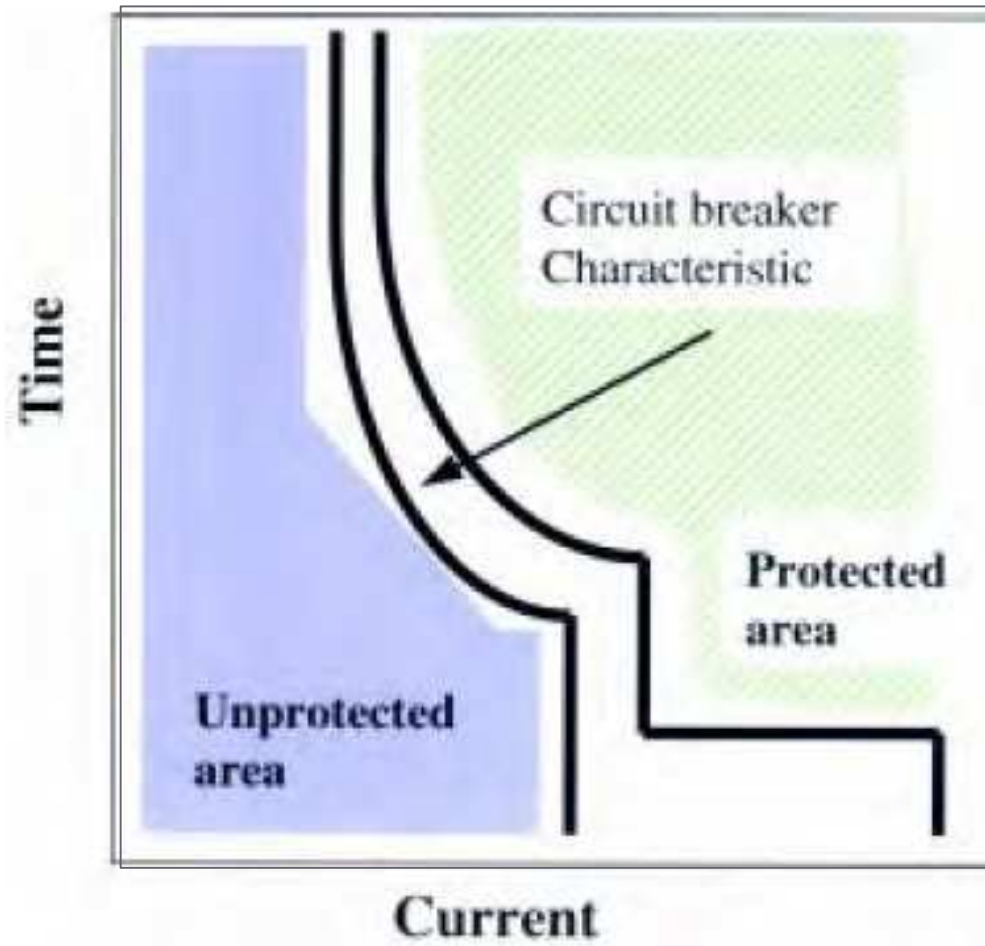
Table 4-1 – Personal Protective Equipment (PPE) Classification as per NIOSH/NIOSH

Arc Flash PPE Category	PPE	Remarks
1	<p>Minimum Arc Rating of 4 cal/cm²</p> <p>Arc-rated long-sleeve shirt and pants or arc-rated coverall</p> <p>Arc-rated face shield or arc flash suit hood</p> <p>Arc-rated jacket, parka, rainwear, or hard hat liner (AH)</p> <p>Protective Equipment</p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SG)</p> <p>Hearing protection (ear canal inserts)</p> <p>Heavy-duty leather gloves</p> <p>Leather footwear (LF)</p>	<p>This rating of PPE is shall be worn at locations where the incident energy level is between 0 cal/cm² and 4 cal/cm²</p>
2	<p>Minimum Arc Rating of 8 cal/cm²</p> <p>Arc-rated long-sleeve shirt and pants or arc-rated coverall</p> <p>Arc-rated flash suit hood or arc-rated face shield and arc-rated balaclava</p> <p>Arc-rated jacket, parka, rainwear, or hard hat liner (AH)</p> <p>Protective Equipment</p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SG)</p> <p>Hearing protection (ear canal inserts)</p> <p>Heavy-duty leather gloves</p> <p>Leather footwear</p>	<p>This rating of PPE is shall be worn at locations where the incident energy level is between 4 cal/cm² and 8 cal/cm²</p>
3	<p>Minimum Arc Rating of 25 cal/cm²</p> <p>Arc-rated long-sleeve shirt (AR)</p> <p>Arc-rated pants (AP)</p> <p>Arc-rated coverall (AC)</p> <p>Arc-rated arc flash suit/jacket (AR)</p>	<p>This rating of PPE is shall be worn at locations where the incident energy level is between 8 cal/cm² and</p>

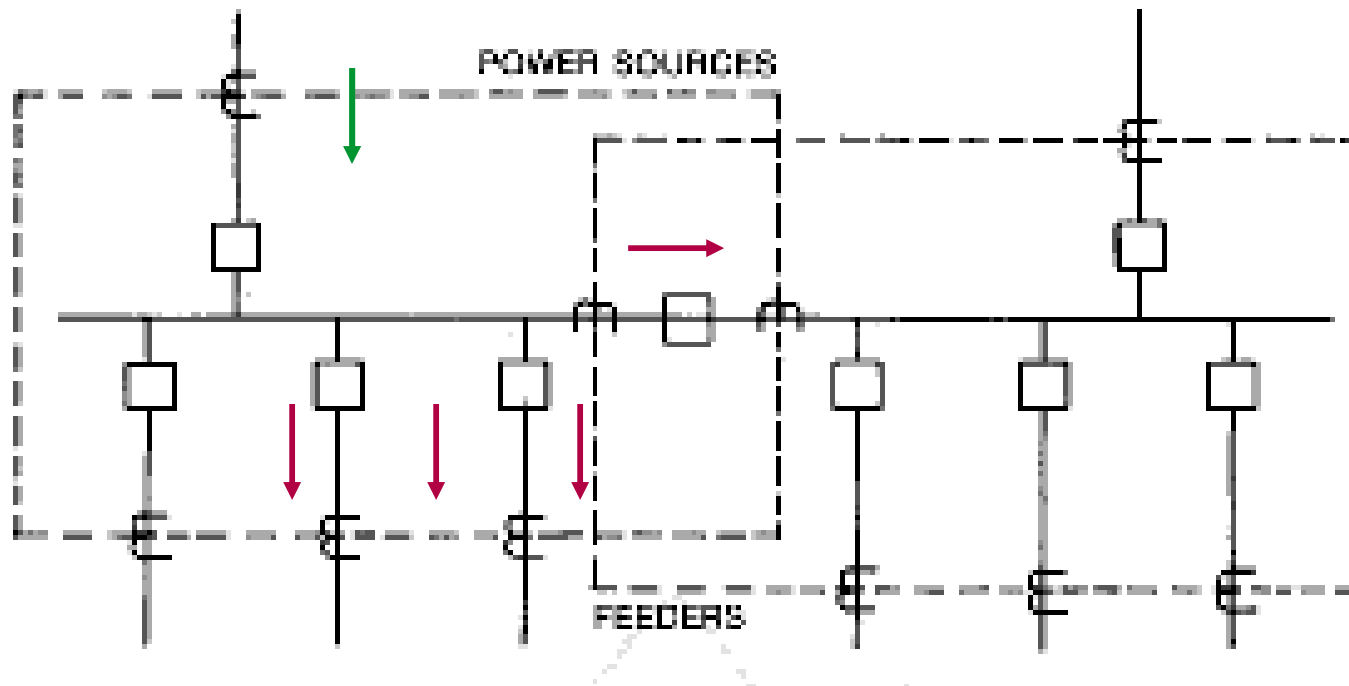
Arc Flash PPE Category	PPE	Remarks
	<p>Arc-rated arc flash suit/pants (AR)</p> <p>Arc-rated arc flash suit hood</p> <p>Arc-rated gloves</p> <p>Arc-rated jacket, parka, rainwear, or hard hat liner (AH)</p> <p>Protective Equipment</p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SG)</p> <p>Hearing protection (ear canal inserts)</p> <p>Leather footwear</p>	<p>25 cal/cm²</p>
4	<p>Minimum Arc Rating of 40 cal/cm²</p> <p>Arc-rated long-sleeve shirt (AR)</p> <p>Arc-rated pants (AP)</p> <p>Arc-rated coverall (AC)</p> <p>Arc-rated arc flash suit/jacket (AR)</p> <p>Arc-rated arc flash suit/pants (AR)</p> <p>Arc-rated arc flash suit hood</p> <p>Arc-rated gloves</p> <p>Arc-rated jacket, parka, rainwear, or hard hat liner (AH)</p> <p>Protective Equipment</p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SG)</p> <p>Hearing protection (ear canal inserts)</p> <p>Leather footwear</p>	<p>This rating of PPE is shall be worn at locations where the incident energy level is at minimum 25 cal/cm² and 40 cal/cm²</p>

Why Arc Flash Protection?

When the traditional time-grading or blocking based protection coordination principle is used, the traditional protection systems may not provide fast enough protection of substation faults. Further, high-impedance type of earth-faults may cause prolonged operation times of earth-fault relays leading to the significant release of the arcing energy. These facts pose a considerable risk to operators and economical assets.



87B Relaying: Sample Schematic

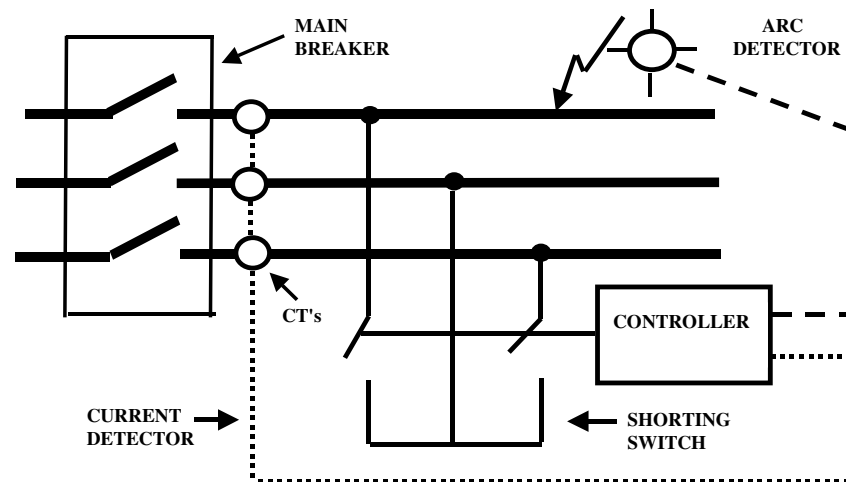


Bus Differential Protection

- **Provides protection for buses and/or switchgear**
- **Sum currents into & out of “zone of protection”**
 - Normally at or near zero (KCL)
 - Non-zero value indicates presence of fault
- **Favorable characteristics for arc-flash:**
 - High-speed (~20 ms relay operating time)
 - Sensitive
 - Compatible with other types of relaying
 - Proven, familiar technology

Arc Terminator System Operation

- Sense a Fault Current
- +
• Detect an Arc
- =
• Close Shorting Switch



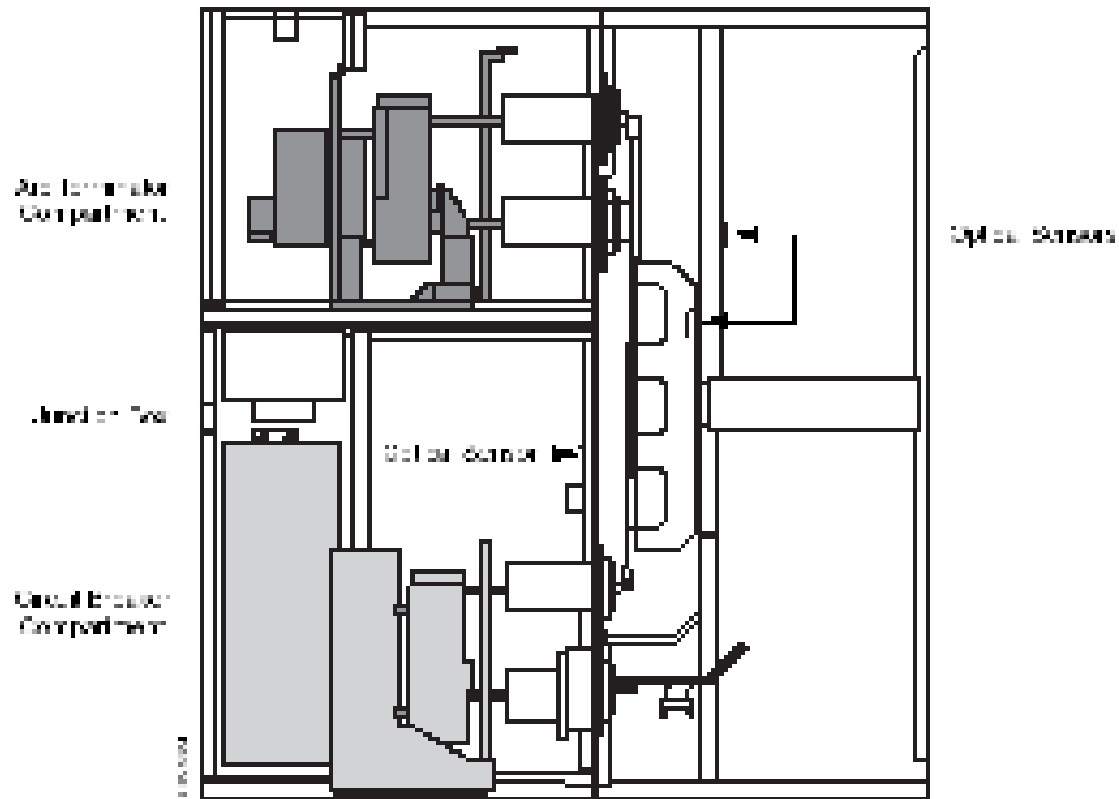
Arc Terminator System Benefits

When Properly Configured, Meets Arc Resistant Standards Plus:

- Reduces incident energy;
- Arc flash hazard reduction
- Reduces pressure buildup
- Reduces release of toxic materials
- Eliminates need for reinforced switchgear
- Eliminates special requirements for buildings or plenums
- Minimizes equipment damage
- Reduces operating downtime



Arc Terminator System Operation



- Section view of an Arc Terminator mounted above a 1200 A circuit breaker in MASTERCLAD switchgear

Arc Terminator System Benefits

Reduces Incident Energy; Arc Flash Hazard Reduction

4.76-15.0 kV Class with Arc Terminator System ¹				4.76-15.0 kV Class without Arc Terminator System ²			
Arcing Fault Current (in kA)	Working Distance (in inches)	Incident Energy (in cal/cm ²)	PPE Level	Arcing Fault Current (in kA)	Working Distance (in inches)	Incident Energy (in cal/cm ²)	PPE Level
25	18	0.46	0	25	18	4.19	2
40	18	0.82	0	40	18	8.91	2
50	18	0.70	0	50	18	6.76	3

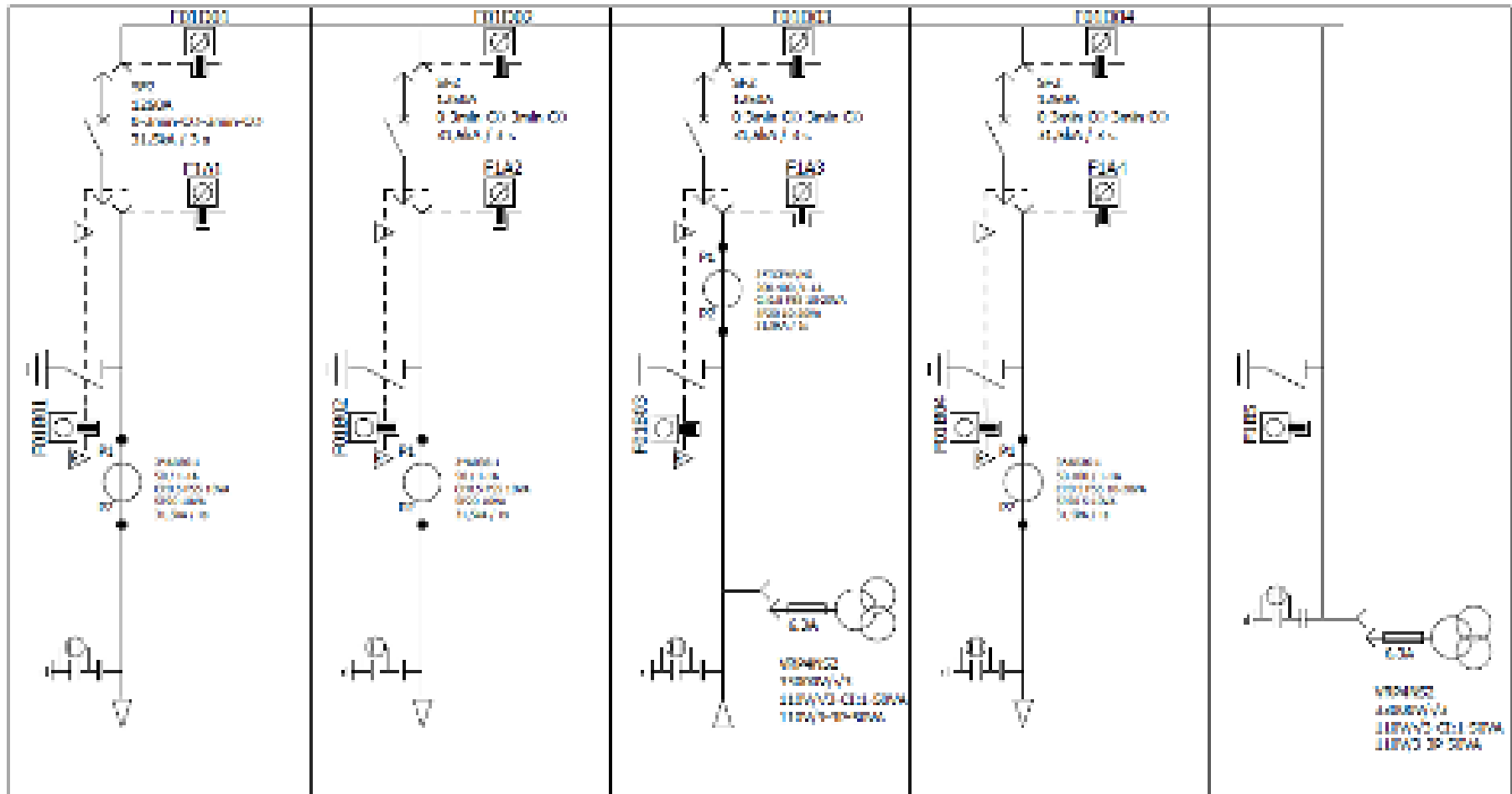
¹Data based upon IEEE Std. 1684-2002 methodology.

Data based upon functional Arc Terminator System.

²Data assumes fault clearing time of 50ms (3 cycles). 6 cycle breakers will have higher incident energy levels.

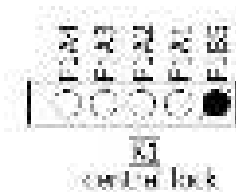
Note: Minimum PPE Level is now changed to 1

HV Switchgear Overview - SLD



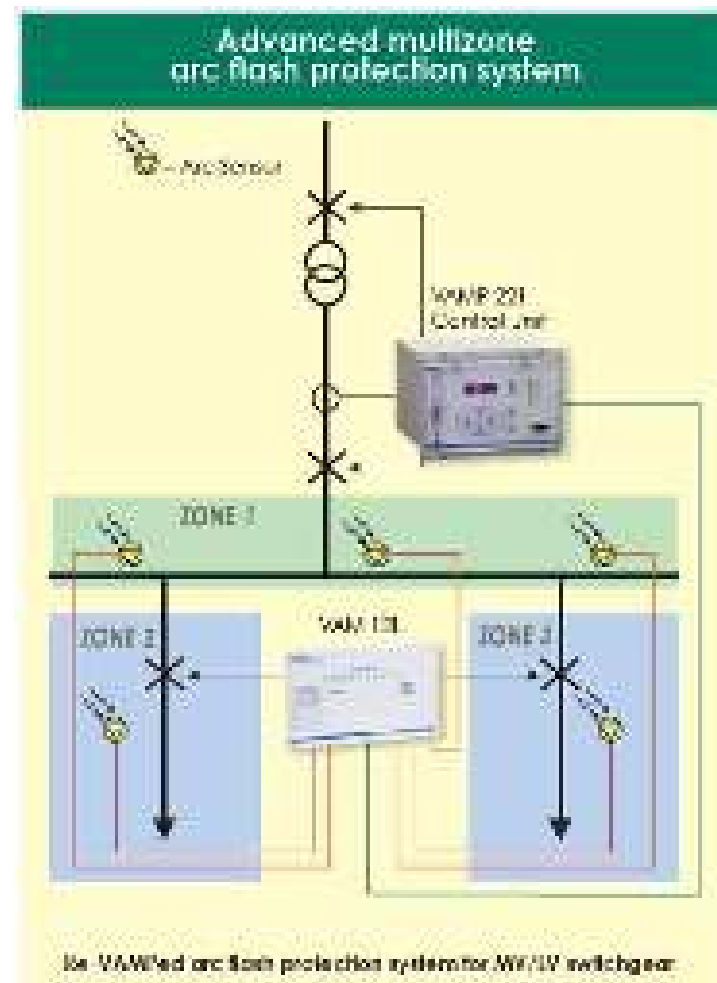
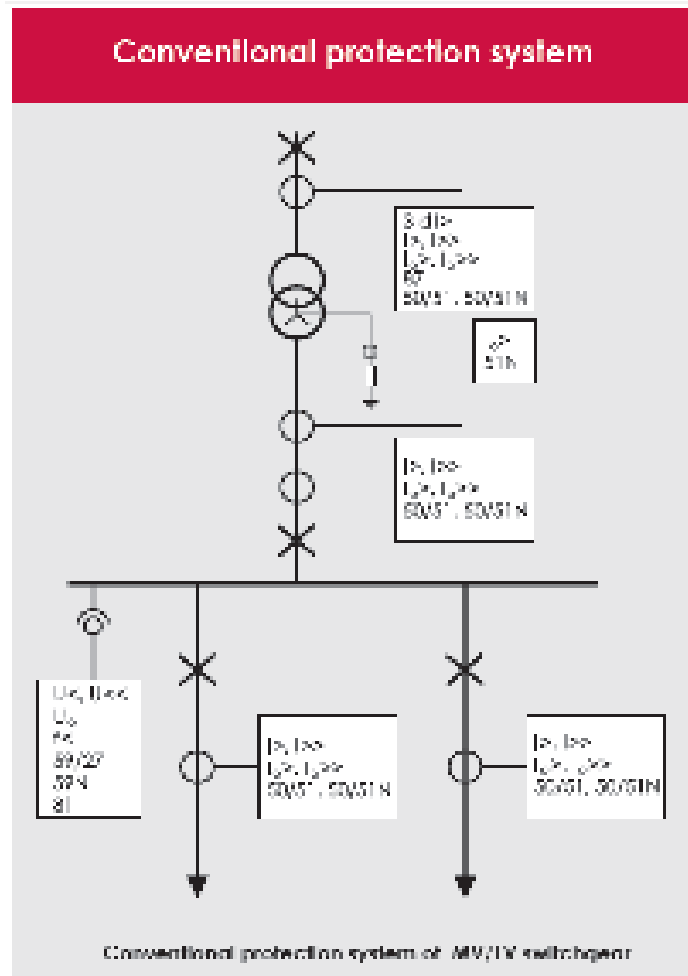
BUSEBAR EARTING INTERLOCKING PRINCIPLE

1. OPEN AND RACK OUT CIRCUIT BREAKERS CIRCLES 1, 1, 2, 1, 3, 1, 1.
 2. INSERT KEYS (F1A1, F1A2, F1A3, F1A4) IN CENTRAL LOCK (K).
 3. REMOVE KEY (F1B) FROM IDENTICAL LOCK.
 4. INSERT KEY (F1B) TO UNLOCK EARTING SWITCH OF 1, 3.
 5. CLOSE EARTING SWITCH MAIN BUSBAR.
- TO RESTORE NORMAL OPERATING CONDITIONS FOLLOW THE ABOVE STEPS BACKWARDS.



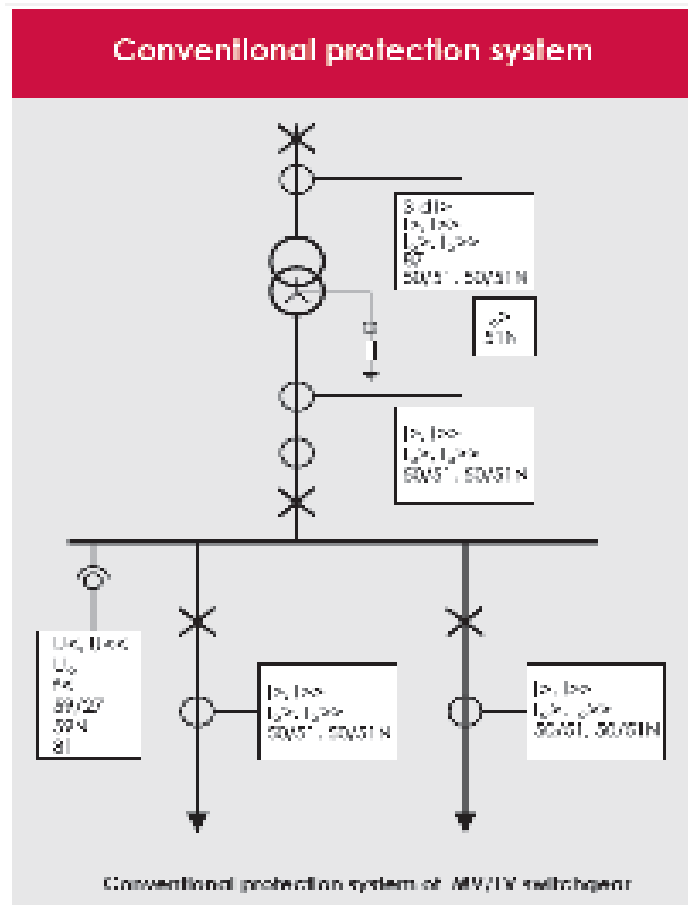
Central lock

Arc Flash Relay and Sensors



Typical waveform of electric arc: Voltage (black) and current (green)

Arc Flash Relay and Sensors

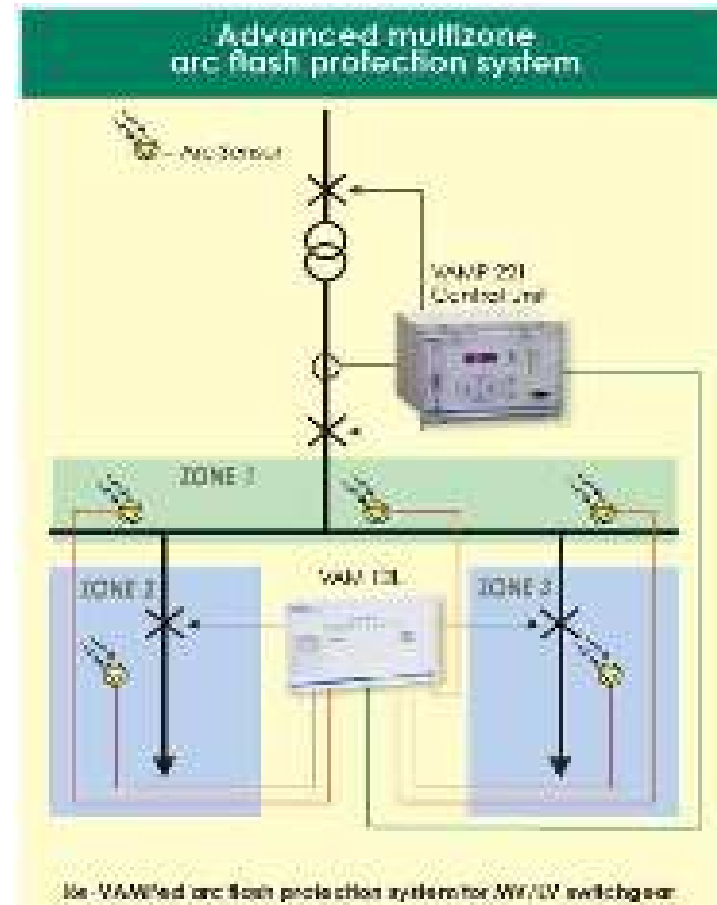


Total fault clearing time typically:

- Outgoing feeder 50 (relay) + 50 (OCR) = 100 ms (+ Auto-reclosing)
- Incoming feeder 300 (relay) + 50 (OCR) = 400 ms

Resistance earthed network

- Fault-fault relay operation times are typically set high, thus burning times of high impedance type arc faults are prolonged.

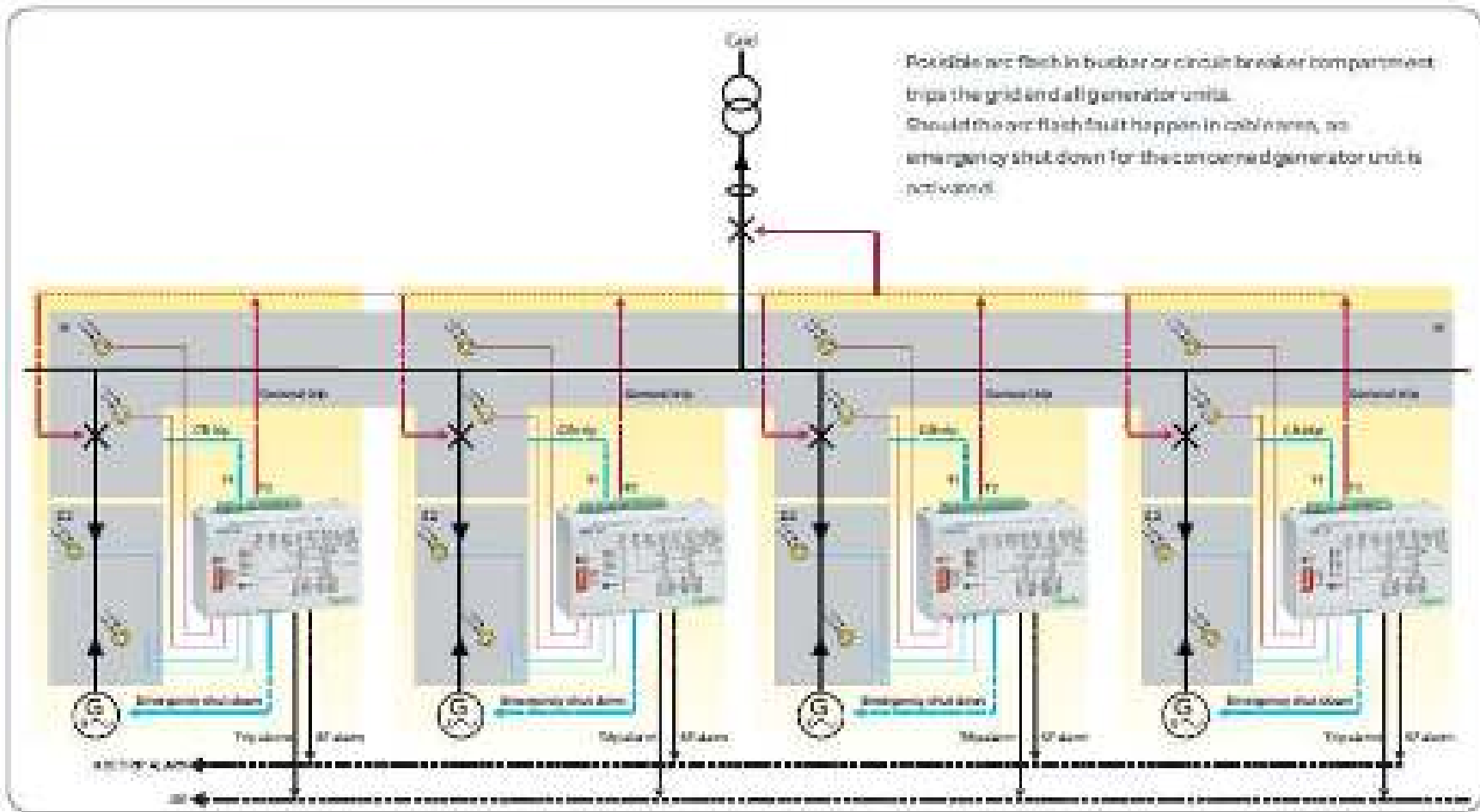


Total fault clearing time typically:

- Outgoing/incoming feeders 7 ms (relay) + 50 ms (OCR) = 57 ms

Resistance earthed network

- Fault clearance in 57 - 64 ms



Benefits of Arc Flash Protection

- Personnel safety
- Reduces Loss of production
- Prolonged Switchgear Life cycle
- Reliable Operation

Electrical safety is like a three-legged stool. One leg depends on a safe installation. *NFPA 70®*, *National Electrical Code®* (*NEC®*), stipulates the installation rules necessary to assure that an electrical installation is safe to operate. The *NEC* establishes safe installation rules for premises wiring systems for residential, commercial, institutional, industrial, and certain utility facilities.

For the second leg of the stool, these electrical installations are kept safe by following the preventive maintenance recommendations required by the manufacturer or those included in *NFPA 70B*, *Recommended Practice for Electrical Equipment Maintenance*. The preventive maintenance program for a facility must include an inspection and testing program that is performed by competent personnel. Electrical equipment must be maintained in order for it to be safely operated under normal conditions.

The third leg of the stool is *NFPA 70E*, which addresses the protection of a worker when exposed to electrical hazards. *NFPA 70E* provides the employer with the direction required to create an electrical safety program (ESP) for the facility. With the employer's ESP following the rules laid out in *NFPA 70E*, the employees ought to be able to select and execute the safety-related work procedures required when the electrical equipment they are interacting with is in other than a normal operating condition.

$$E = \frac{793 \times F \times V \times t_a}{D^2}$$

where:

- E = incident energy, cal/cm²
- F = bolted fault short-circuit current, kA
- V = system phase-to-phase voltage, kV
- t_a = arc duration, sec
- D = distance from the arc source, in.

D.4.5 Arc Flash Boundary. The arc flash boundary is the distance at which a person is likely to receive a second degree burn. The onset of a second degree burn is assumed to be when the skin receives 5.0 J/cm² of incident energy.

For the empirically derived equation,

$$D_{fb} = \left[4.788C_f C_e \left(\frac{t}{0.2} \right) \left(\frac{610^2}{E_b} \right) \right]^{\frac{1}{2}} \quad \text{[D.4.5a]}$$

For the theoretically derived equation,

$$D_{fb} = \sqrt{2.142 \times 10^7 V_{ph} \left(\frac{t}{I_{sc}} \right)} \quad \text{[D.4.5b]}$$

where:

- D_{fb} = distance (mm) of the arc flash boundary from the arcing point
- C_f = calculation factor
 - = 1.0 for voltages above 1 kV
 - = 1.5 for voltages at or below 1 kV
- C_e = incident energy correction factor
- t = time, sec
- x = distance exponent from [Table D.4.2](#)
- E_b = incident energy in J/cm² at the distance of the arc flash boundary
- V = system voltage, kV
- I_{sc} = bolted three-phase available short-circuit current

International Note: These equations could be used to determine whether selected personal protective equipment (PPE) is adequate to prevent thermal injury at a specified distance in the event of an arc flash.



Questions

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