

NFPA 70E Arc Flash Considerations for MV Equipment

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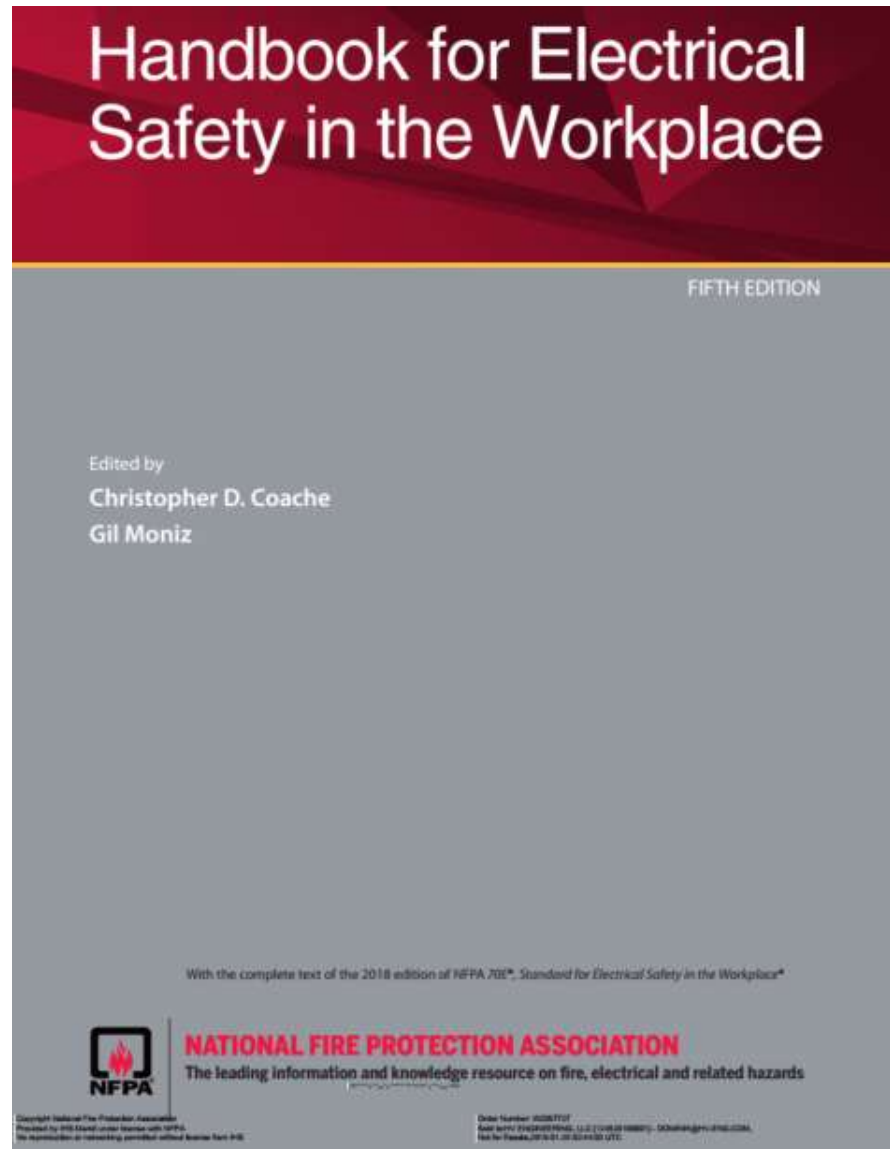
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Major Changes to NFPA 70E - 2018

Greater emphasis on Risk Assessment:

- Identify hazards
- Estimate likelihood of occurrences
- Estimate potential severity of injury
- Determine if protective measures are required

NFPA 70E – 2018 Handbook



NFPA 70E – 2018 Handbook

NFPA 70E Summary of Technical Changes: 2018

2018 Section	Comments	FR/SR Reference
Electrical Safety Program	Added definition providing the pertinent components of an electrical safety program to enhance clarity and usability of the standard.	FR 13
Electrically Safe Work Condition	Added the adjective "temporary" to more accurately describe the term used in 120.5(8). Replaced "ensure" with "verify" to more accurately describe the result of the voltage test.	FR 11, SR 4
Enclosed	Revised language for consistency with other recognized occupational health and safety standards.	FR 80
Enclosure	Revised language for consistency with other recognized occupational health and safety standards.	FR 80
Fault Current	Added definition of a term used throughout the standard.	SR 8
Fault Current,	Added definition of a term used throughout the standard.	SR 8

List of changes

Explanations/ discussions/ examples

(8) Where the possibility of induced voltages or stored electrical energy exists, ground the phase conductors or circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

The purpose of temporary grounding is to provide protection against electrical shock to personnel while working on de-energized circuits. Temporary protective grounds are critical safety devices used to create a circuit path so that the circuit overcurrent protective device can operate upon accidental energizing of the circuit. De-energized circuits could be accidentally energized from many energy sources, including human error (such as switching errors), equipment failure, mechanical failure, stored charges from capacitors, static buildup, or induced voltage feedback from adjacent circuits. Exhibit 120.15 shows a 3-phase system with temporary grounding installed.

Worker Alert

Applying temporary protective grounding equipment is the last step in establishing an electrically safe work condition (ESWC). You are required to use PPE for all steps of establishing the ESWC. Temporary grounding is not necessary for all ESWC.

Case Study

130.4(F)

Scenario

Don was a self-employed HVAC technician with a small company that also employed two other technicians. Don had worked in the industry for 42 years. He received a service call from a home-

The homeowner quickly called 911 and was instructed to open the breaker to the AC unit since she knew the location of the circuit breaker panel. When the EMTs arrived they found Don was unresponsive. One of his hands was near an exposed conductor and his other near the AC unit's metal housing.

Case studies

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Last Class Question by Mike Wactor

TABLE 130.7(C)(15)(a) Arc-Flash PPE Categories for Alternating Current (ac) Systems

<i>Equipment</i>	<i>Arc-Flash PPE Category</i>	<i>Arc-Flash Boundary</i>
Arc-resistant switchgear 1 kV through 15 kV [for clearing times of less than 0.5 sec (30 cycles) with an available fault current not to exceed the arc-resistant rating of the equipment], and metal-enclosed interrupter switchgear, fused or unfused of arc-resistant-type construction, 1 kV through 15 kV	N/A (doors closed)	N/A (doors closed)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4 (doors open)	12 m (40 ft)

I interpret this section as follows:

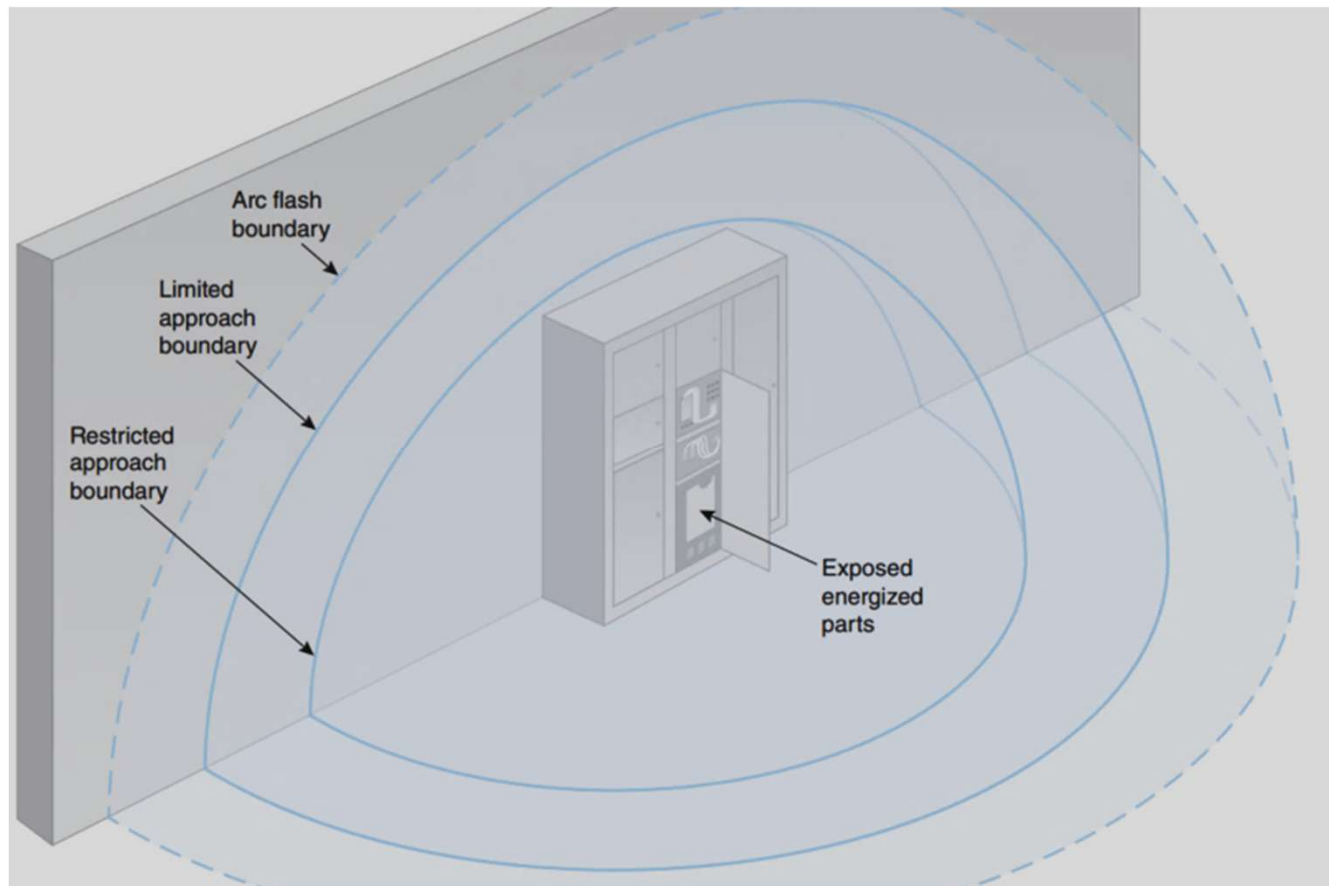
1. If equipment is arc-resistant or arc-resistant-type...AND clearing time is < 0.5 sec...AND doors **CLOSED**...
THEN there is no requirement for AF PPE, and there is no AF boundary
(Normal Operating Condition is implied)
2. If equipment is arc-resistant or arc-resistant-type...AND clearing time is < 0.24 sec...AND minimum work distance $\leq 36''$...AND S.C. ≤ 35 kA...AND doors **OPEN**.....
THEN AF PPE Category 4 is required AND AF boundary is 40 ft.

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

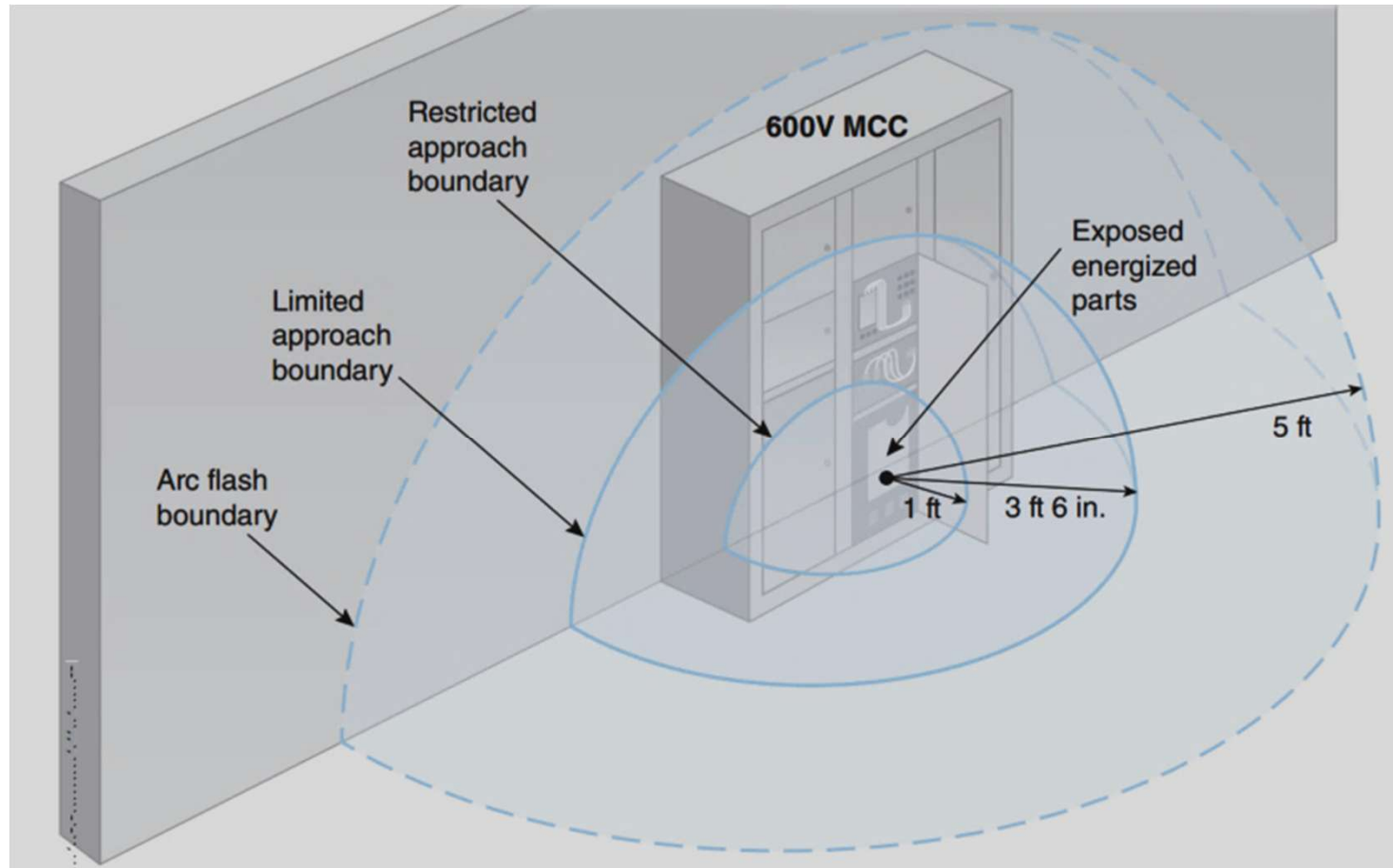
(1) <i>Nominal System Voltage Range, Phase to Phase^a</i>	(2) <i>Limited Approach Boundary^b</i>		(4) <i>Restricted Approach Boundary^b; Includes Inadvertent Movement Adder</i>
	<i>Exposed Movable Conductor^c</i>	<i>Exposed Fixed Circuit Part</i>	
Less than 50 V	Not specified	Not specified	Not specified
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.)

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An example of boundaries. The arc flash boundary is a calculated value...5ft shown as an example

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Qualified Person (100):

One who has demonstrated skills and knowledge related to construction and operation of electrical equipment and installations and has received safety training **to identify the hazards and reduce the associated risks.**

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Condition of Maintenance (100):

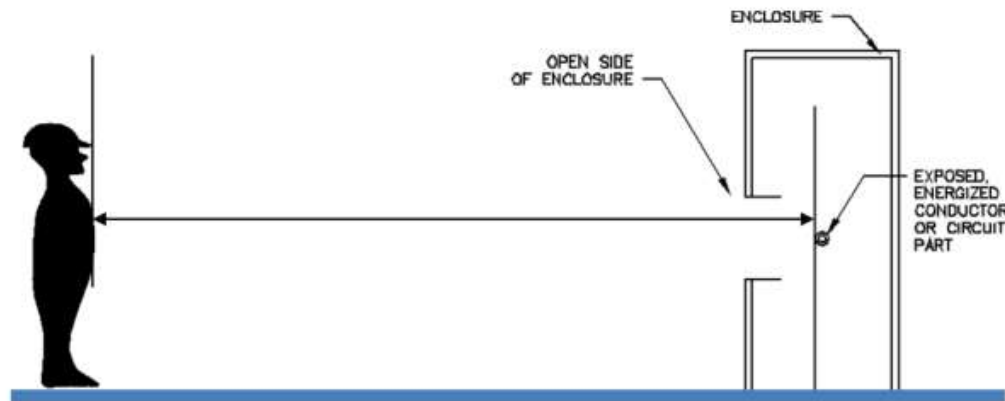
The state of electrical equipment considering the manufacturers' recommendations and applicable industry codes, standards, and recommended practices.



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Working Distance(100):

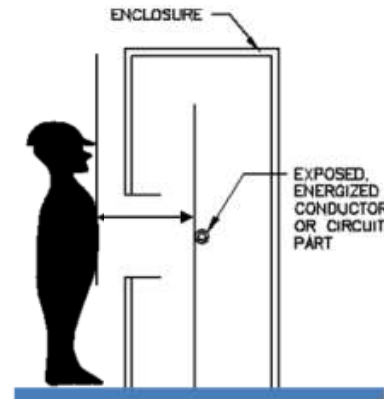
The distance between a person's face and chest area and a perspective arc source



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Working Distance(100):

The distance between a person's face and chest area and a perspective arc source



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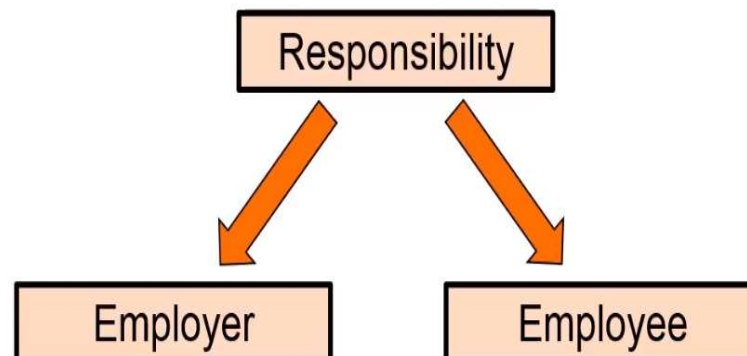
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Responsibility (105.3):

This section was revised and subdivided into “Employer Responsibility” and “Employee Responsibility”

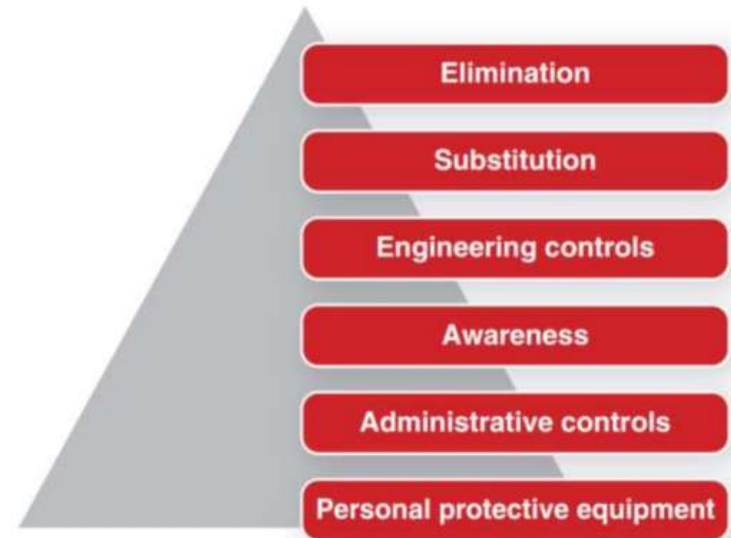
Now the employee is required to comply with the safety-related work practices and procedures provided by the employer.



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Risk Assessment Procedure (110.1.H):

- Identify hazards
- **Human error**
- **Hierarchy of Risk Control Methods** (*previously info. note*)
 - Elimination
 - Substitution
 - Engineering Controls
 - Awareness
 - Admin Controls
 - PPE



Detailed in Informative Annex Q

Major Changes to NFPA 70E - 2018

Electrically Safe Condition (**130.2**):

Energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 ~~Vac or 100 Vdc~~ volts shall be put into an electrically safe work condition before an employee performs work if any of the following conditions exist:

Major Changes to NFPA 70E - 2018

(required to be put into electrically safe condition)

- If work is being performed in the limited approach boundary
- Interaction clause: The employee interacts with equipment where conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists.

The exception regarding disconnecting means or isolating element was deleted (next slide)...

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Exception: Where a disconnecting means or isolating element that has been properly installed and maintained is operated, opened, closed, removed, or inserted to achieve an electrically safe work condition for connected equipment or to return connected equipment to service that has been placed in an electrically safe work condition, the equipment supplying the disconnecting means or isolating element shall not be required to be placed in an electrically safe work condition provided a risk assessment is performed and does not identify unacceptable risks for the task.

If an enclosed fusible safety disconnect or an enclosure circuit breaker disconnect is nipped to an industrial control panel and used to create an ESWC, since the live conductors to the main lugs of the disconnect are not exposed when the industrial control panel doors are opened, the risk assessment should identify the risk as acceptable, unless there is another power source into the industrial control panel that has not been properly locked out. A similar situation is where the industrial control panel has two doors and the compartment containing the disconnect switch has a separate door and is completely barriered and sealed off from the other compartment in a manner similar to that of a nipped enclosed disconnect. Under either of these scenarios, the equipment supplying the disconnect would not be required to be put in an ESWC.



This was deleted

Major Changes to NFPA 70E - 2018

Normal Operation (130.2.A.4) – all conditions are satisfied

- Equipment is properly installed
- Equipment is properly maintained
- **The equipment is used in accordance with instructions included in the listing and labelling and in accordance with mfr's instructions**
- Equipment doors are closed and secured
- All covers in place and secured
- No evidence of impending failure

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When is Energized Electrical Work Permit Required (130.2.B.1)

- When work is performed as permitted in accordance with 130.2(A), an energized electrical work permit shall be required **and documented** under any of the following conditions:
 - When work is performed within the restricted approach boundary
 - Interaction can increase likelihood of injury from an arc flash

Major Changes to NFPA 70E - 2018

NEW Table 130.5(G) Selection of Arc-Rating Clothing and other PPE when incident energy analysis method is used.

This table was added and “shall be permitted to be used with the incident energy analysis method for selecting arc flash PPE.”

Derived from Annex Table H.3(b) in 2015 edition

Major Changes to NFPA 70E - 2018

TABLE 130.5(G) *Selection of Arc-Rated Clothing and Other PPE When the Incident Energy Analysis Method Is Used*

Incident energy exposures equal to 1.2 cal/cm² up to 12 cal/cm²

Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy^a

Long-sleeve shirt and pants or coverall or arc flash suit (SR)

Arc-rated face shield and arc-rated balaclava or arc flash suit hood (SR)^b

Arc-rated outerwear (e.g., jacket, parka, rainwear, hard hat liner) (AN)

Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with leather protectors (SR)^c

Hard hat

Safety glasses or safety goggles (SR)

Hearing protection

Leather footwear

Incident energy exposures greater than 12 cal/cm²

Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy^a

Long-sleeve shirt and pants or coverall or arc flash suit (SR)

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Exception No. 1 (**130.5.H**) for labels:

Unless changes in electrical distribution system(s) render the label inaccurate, labels applied prior to the effective date of this edition of the standard shall be acceptable if they complied with the requirements for equipment labelling in the standard in effect at the time the labels were applied.

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Exception No. 2 for existing labels:

In supervised industrial installations where the conditions of maintenance and engineering supervision ensure that only qualified persons monitor and service the system, the information required in 130.5(H)(1)-(3) shall be permitted to be documented in a manner that is readily available to persons likely to perform examination, servicing, maintenance, and operation of the equipment while energized.

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Personal and Other Protective Equipment (**130.7**):

130.7(A) Informational Note #2 (deleted):

Informational Note No. 2: It is the collective experience of the Technical Committee on Electrical Safety in the Workplace that normal operation of enclosed electrical equipment, operating at 600 volts or less, that has been properly installed and maintained by qualified persons is not likely to expose the employee to an electrical hazard.

This note has been deleted.

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130.7(A) Informational Note #3:

Note regarding the 40 cal/cm^2 at the working distance...greater emphasis may be necessary with respect to de-energizing **has been deleted.**

Consider a 40 cal/cm^2 with 3 cycle clearing time vs. 2 second clearing time

Instead, a greater emphasis should always be placed on de-energizing...

...not just above 40 cal/cm^2

Avoiding Hazards

De-energize the circuit!!

Per OSHA 1910.333(a)(1), live parts to which an employee may be exposed must be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations. (Live parts that operate at less than 50 volts to ground need not be de-energized if there will be no increased exposure to electrical burns or to explosion due to electric arcs.)

The message is clear: never work on live circuits unless it is absolutely necessary. OSHA allows work on live circuits in some cases, but the reason cannot be simply that turning off the power is inconvenient or will interrupt production. Nor can workers use the excuse that they didn't have the authority to shut off power.

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Flash Protection Boundary

The arc flash boundary for systems 50 volts and greater is the distance at which the incident energy equals 1.2 cal/cm^2 (5 J/cm^2).

This is the onset of a 2nd degree burn...

.....which is recoverable



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Arc Flash Boundary 130.5(E)

Public consensus is that, should an arc flash occur while an employee is performing a task on justified energized electrical equipment, the employee should be able to survive without permanent physical damage. Testing has concluded that 1.2 cal/cm^2 is the level at which exposed skin can suffer the onset of a second-degree burn. See the commentary following the term *arc flash hazard* in Article 100 regarding second-degree burns.

Properly rated PPE should limit the employee's injury to a second-degree burn if an arc flash were to occur while performing work within the arc flash boundary. **There is no requirement to provide the employee with arc flash protection when the incident energy is below 1.2 cal/cm^2 since the expected injury from an incident will be survivable and nonpermanent**

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PPE

Remember: PPE is the last line of defense. PPE cannot prevent all injuries and will only lessen the impact of an arc flash. In many cases the use of PPE has saved lives or prevented serious injury.

National trend is single layer Arc Flash PPE Category 2 daily wear and Arc Flash PPE Category 4(or greater) flash suit.

Always wear arc rated clothing as the outermost layer



Other Arc Flash Considerations

Short circuit levels exceed equipment ratings

- The incident energy calculations are based on protective devices having the ability to clear the fault within a preset time.
- If the protective device can not interrupt the fault, the device can fail (leading to other issues) and will require the upstream device to clear the fault...adding additional time.

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Arc Flash Mitigation via Engineering Controls

- System design
- Selection of equipment
 - Proper ratings (S.C., AF Time, etc)
 - Proper application
 - On-line diagnostics (i.e. partial discharge)
- Protection schemes
- Maintenance Switches
- Remote operation (including racking in/out)

Arc Flash Mitigation

- System design such that de-energizing of source is always possible, HRG (for LV equip).
- Arc-resistant switchgear
- Fast acting protection schemes (diff, zone selective interlocking, arc detection, etc)
- Maintenance / alternate settings
- Remote operation including racking in/out

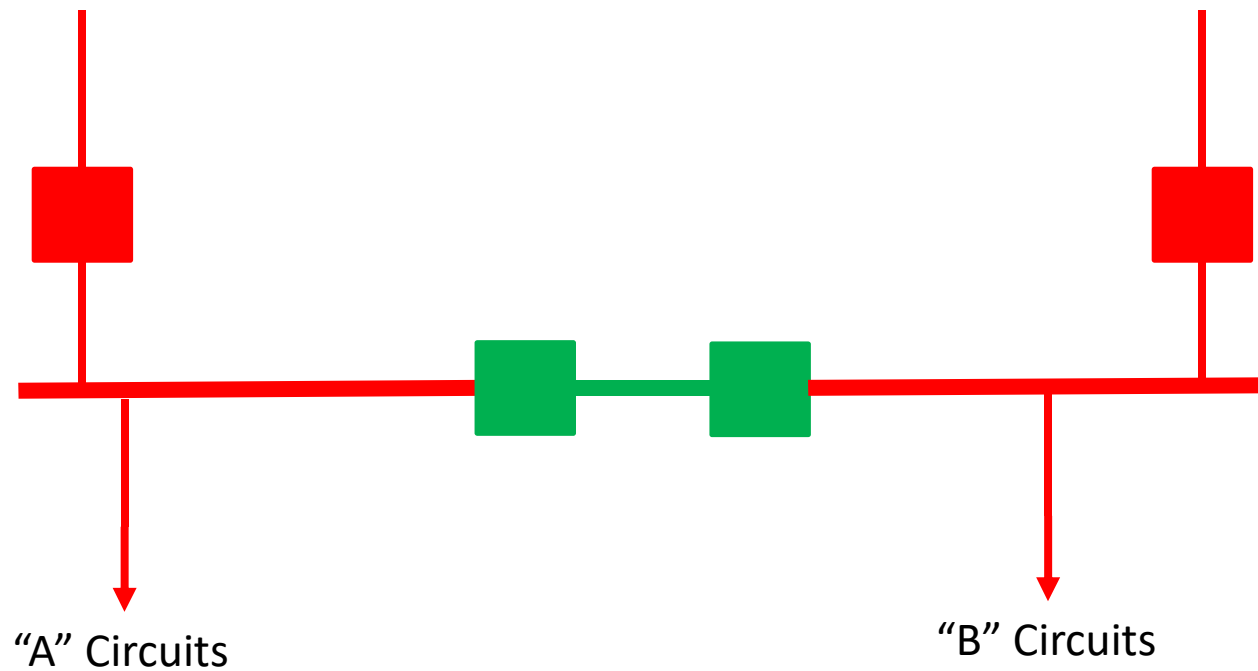
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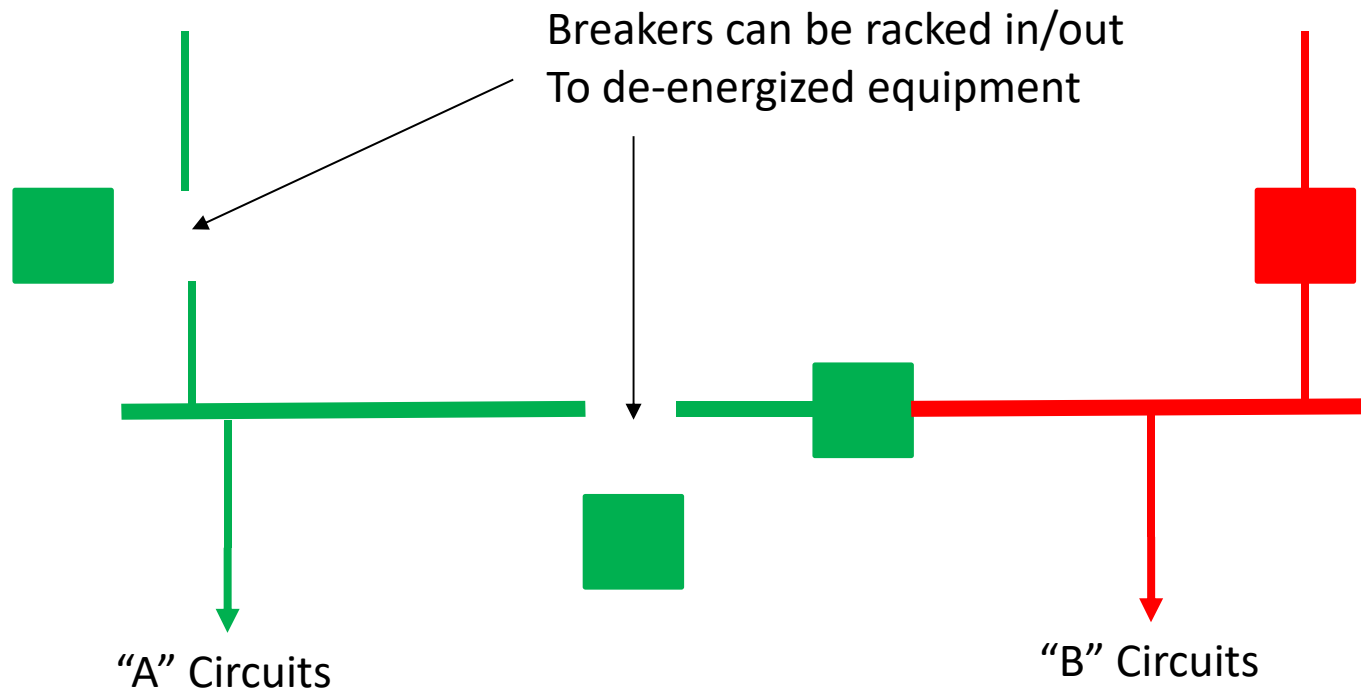
Arc Flash Mitigation De-Energize Equipment

- Main-Tie-Tie-Main



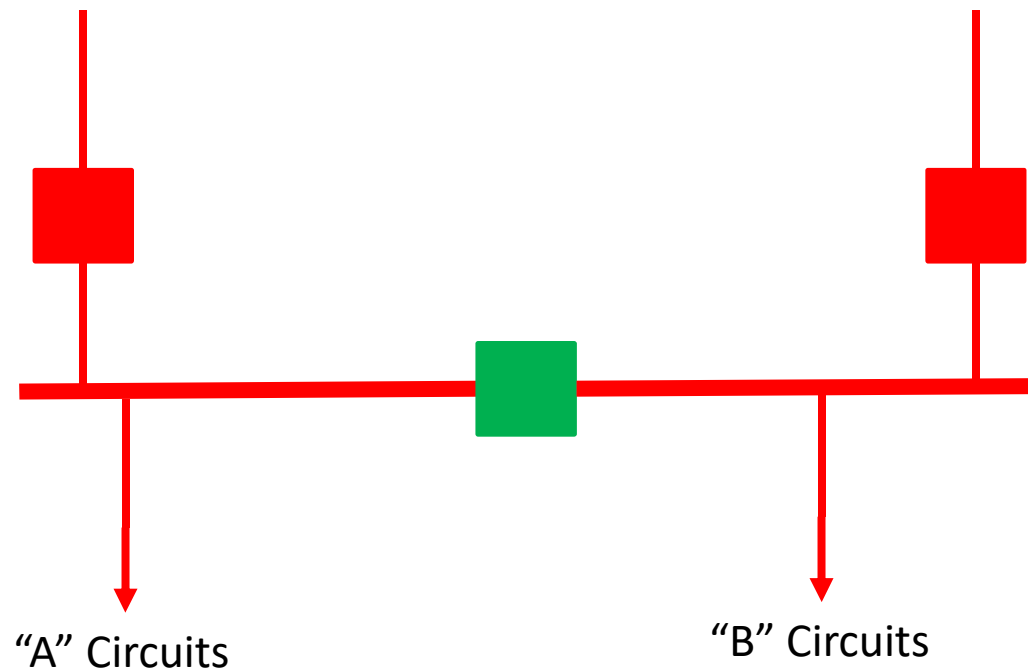
Arc Flash Mitigation De-Energize Equipment

- Main-Tie-Tie-Main



Arc Flash Mitigation De-Energize Equipment

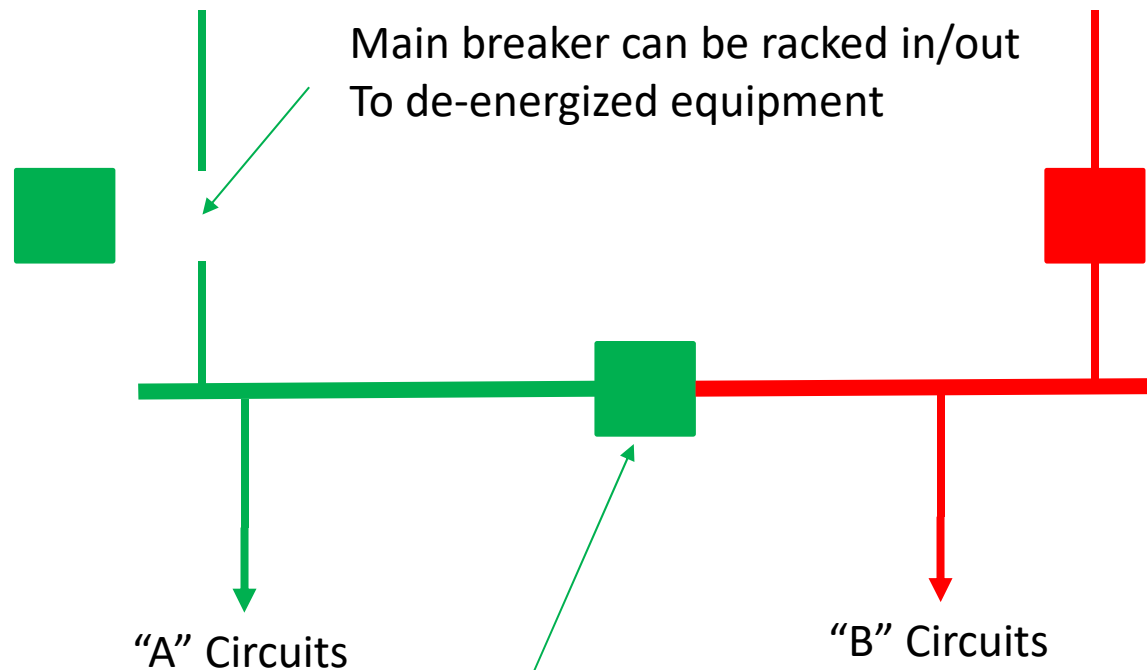
- Main-Tie-Main



Tie Breaker is always energized until both buses are de-energized

Arc Flash Mitigation De-Energize Equipment

- Main-Tie-Main



Tie Breaker is always energized from at least one side until both buses are de-energized

Arc Flash Mitigation

Arc Flash Containment

- Arc Resistant Equipment



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Containment means that it protects you from the flash hazard, and more importantly it protects you from the pressure wave.

Arc Flash Mitigation

Arc Flash Containment

- Arc Resistant Equipment

But do you still need calculations and labels?

What happens when the doors are open, panels removed ?

...or not installed properly (i.e. panels left open, openings not sealed properly)

...or if clearing time is greater than rated (typ 0.5 seconds)

Arc Flash Mitigation

Arc Flash Containment

- Arc Resistant Equipment

But do you still need PPE if operating within ratings and door closed?

Recall that AR swgr limits the amount of thermal energy external to the switchgear...such that ignition of the indicators does not occur. The standard allows:

“Holes in horizontally mounted indicators caused by particles that do not ignite the indicator are ignored.”

Those particles could still cause harm to personnel.

Arc Flash Mitigation

Arc Flash Containment

- Arc Resistant Equipment

But do you still need PPE?



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Arc Flash Mitigation

Arc Flash Containment

- Arc Resistant Equipment

But do you still need PPE?



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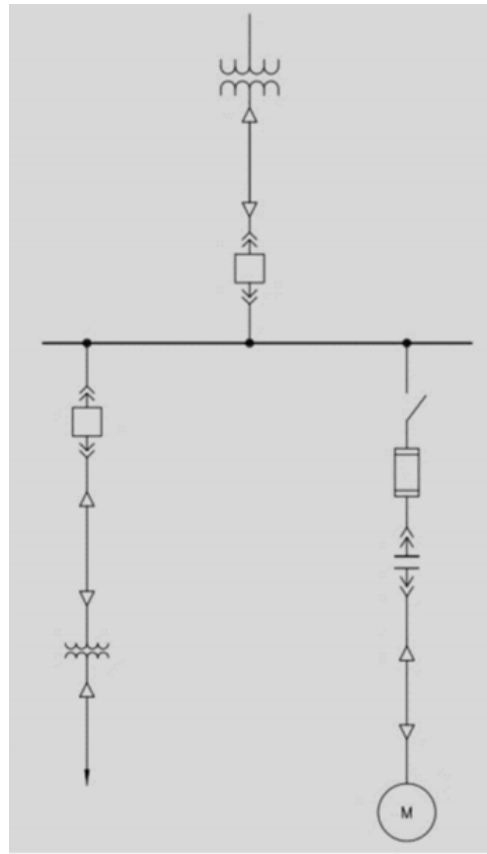
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Arc Flash Mitigation

Arc Resistant Swgr

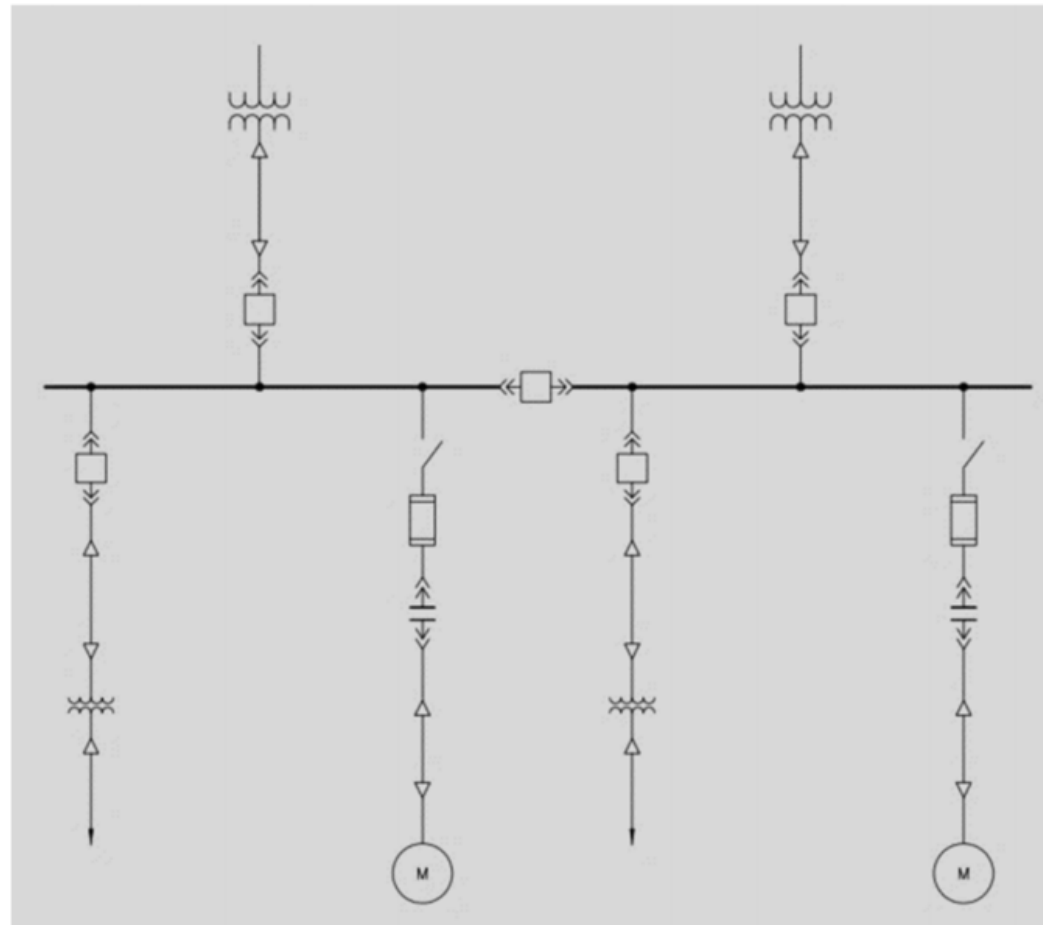
- The preferred arcing duration for this test are 0.5 sec for MV and 0.1 sec for LV Swgr. That works great for high impedance loads...(i.e. motors, transformers, etc) on a radially fed bus



Arc Flash Mitigation

Arc Resistant Swgr

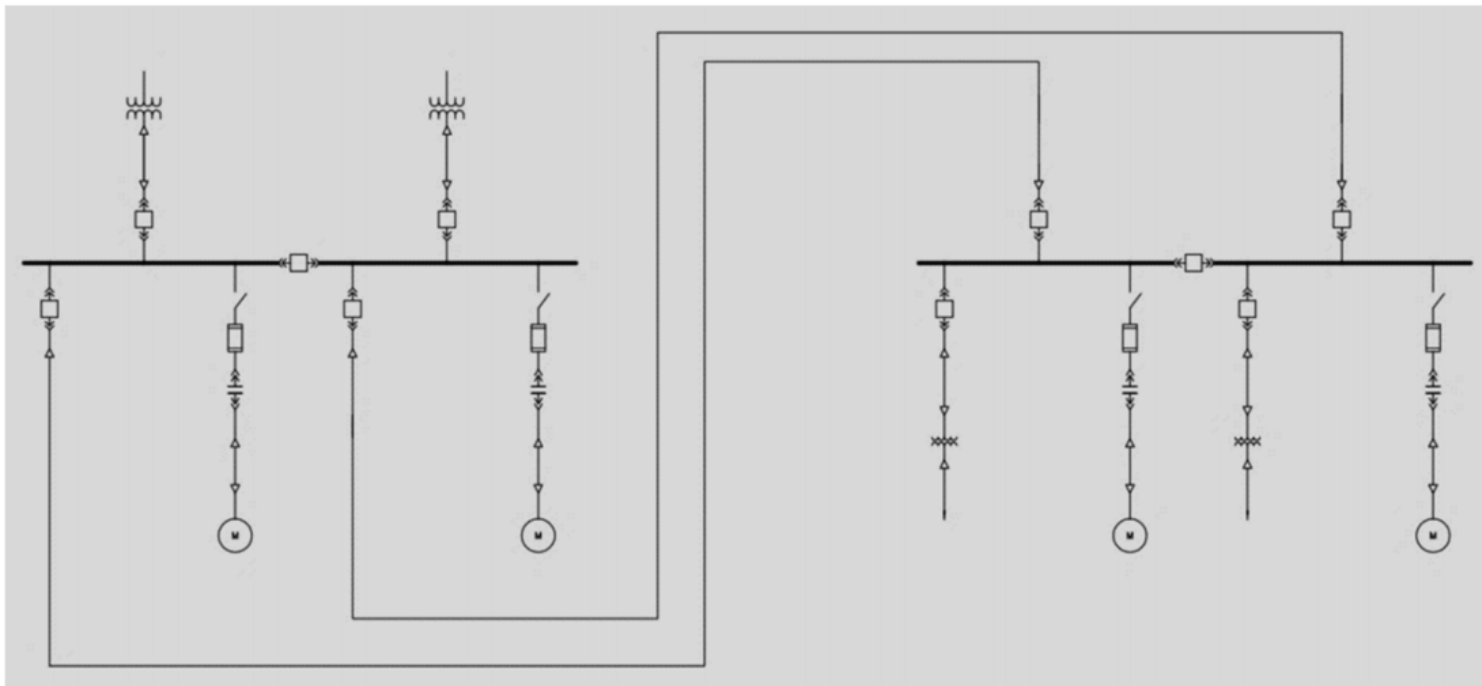
- ...a little more tricky if you are trying to include coordination for tie breaker



Arc Flash Mitigation

Arc Resistant Swgr

- ...and impossible for a bus that feeds a remote bus



Arc Flash Mitigation

Arc Resistant Swgr

Does this mean that you can not use AR Swgr for these applications?

No.....Short of de-energizing equipment, containment of the arc flash is your best means of protection of personnel

This just means that you have to give a little more thought to the specification of the equipment:

- Longer arc flash time rating (1 sec or 2 sec)....but this will add significant cost
- Addition of arc flash mitigation protection
 - Fast acting differential protection
 - Arc flash sensing protection

You have to better define your objective, understand the applications (understand the limitations that the ratings/design will create)....and probably most importantly budget constraints.

Arc Flash Mitigation

Arc Resistant Swgr

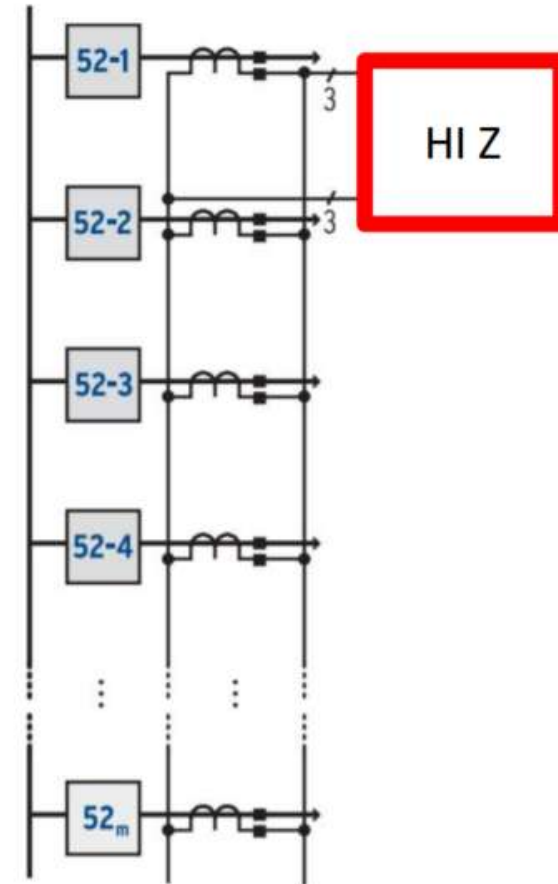
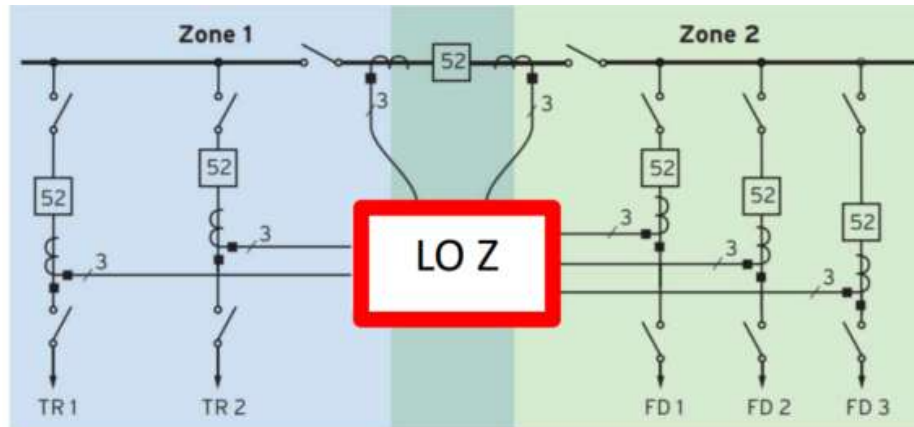
Also, don't forget that AR swgr will protect you from the pressure wave that causes physical damage within the first cycle of the arcing fault.

Arc Flash Mitigation Protection Schemes

- High-speed differential protection
 - CTs define zones of protection
 - Multiple CTs / wiring
 - Specialty relay (high impedance or low impedance)
 - High-speed tripping
 - Difficulties with MCCs
 - CT placement
 - Contactor ratings
 - Contactor opening time



Arc Flash Mitigation Protection Schemes



Arc Flash Mitigation Protection Schemes

- Arc Flash Detection
 - Addition of F.O. sensors
 - Point sensors
 - Bare fiber sensors
 - Many O/C relays have option for F.O. interface
 - Susceptibility to light...requires current supervision
 - Difficulties with MCCs
 - Contactor ratings
 - Contactor opening time

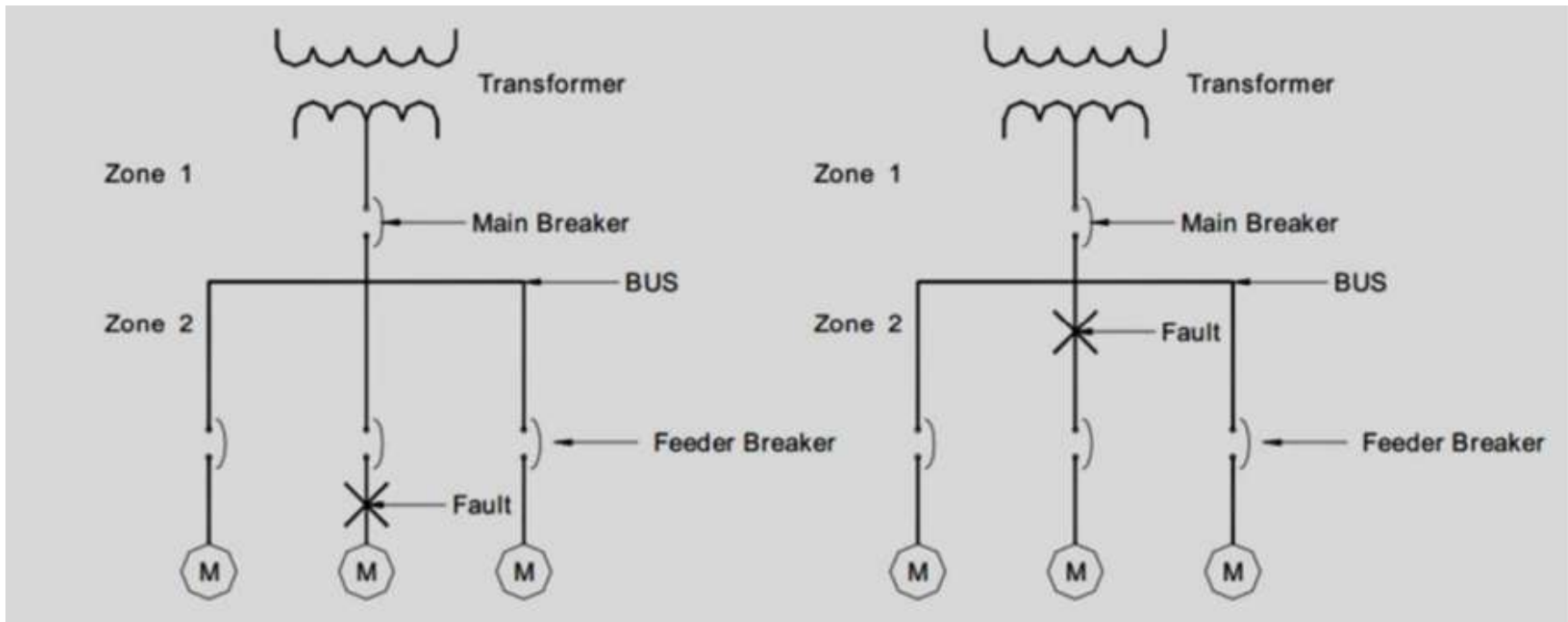
Arc Flash Mitigation Protection Schemes



Arc Flash Mitigation Protection Schemes

- Zone Selective Interlocking
 - CTs define zones of protection
 - Communications between relays
 - Many O/C relays have option for ZSI
 - Small time delay
 - Difficulties with MCCs
 - Contactor ratings
 - Contactor opening time

Arc Flash Mitigation Protection Schemes



Arc Flash Mitigation Protection Schemes

- Remote operation
 - DCS controls
 - Chicken Switch
 - Remote Racking

Gets personnel away from equipment

Arc Flash Mitigation Working Distance

After market remote racking
devices



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Arc Flash Mitigation Working Distance



(Swgr can be specified with closed door racking)

Provided with camera

Mfgs can provide accessories so that remote racking devices can be attached with doors closed.



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Arc Flash Mitigation Working Distance

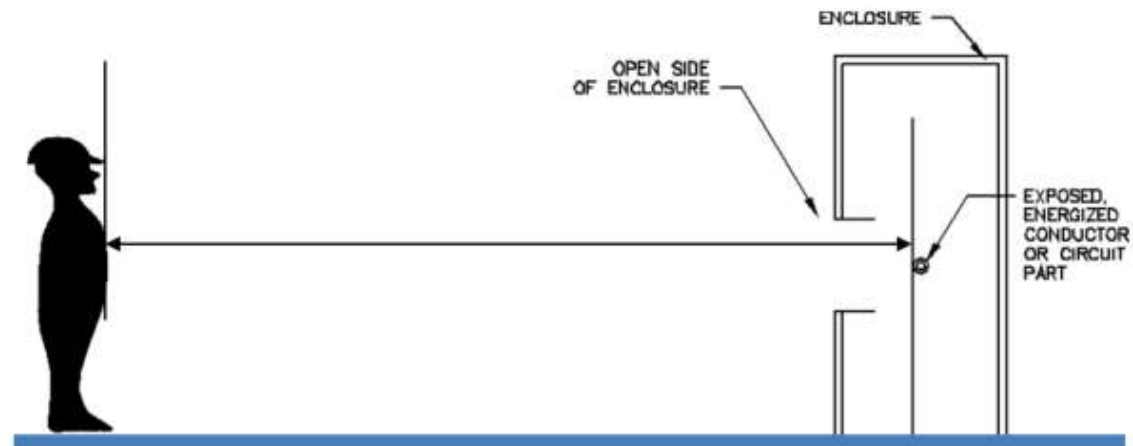
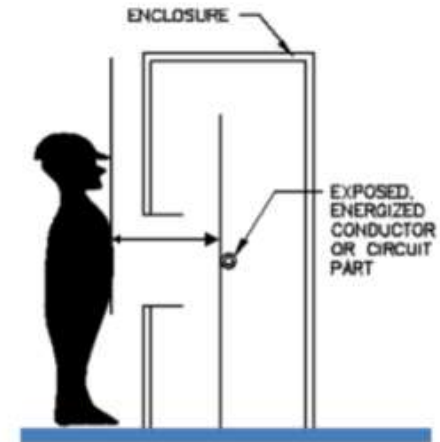


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Arc Flash Mitigation Working Distance



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Arc Flash Mitigation Working Distance



Arc Flash Mitigation Protection Schemes

- Maintenance Switch

Applies alternate (lower) settings to upstream protection which reduces time to trip...

...however during this time, coordination is compromised.

And don't walk away without changing back!

Arc Flash Mitigation Protection Schemes

- Modern relays can provide alternate setting groups which can be activated remotely (via D.I. to relay) or locally at the relay.

Never a good idea to change settings on the fly without testing...The second/alternate setting group should be set/tested ahead of time.

Arc Flash Mitigation Protection Schemes

- For older relays/schemes
 - New relay can be added
 - Spare contacts can be used

Via a selector switch.

Contact from selector switch should sound alarm horn or turn on strobe light, such that you do not walk away in the reduced setting position.

Arc Flash Mitigation

Working Distance

- Arc flash hazards at MV Swgr/MCC are typically more manageable than LV Swgr/MCC due to:
 - Working distances
 - Magnitude of arcing fault

Arc Flash Mitigation

Working Distance: IEEE 1584-2002

Class of Equipment	Typical Working Distance Inches (cm)
Cable	18 (46)
Low-voltage MCCs and panelboards	18 (46)
Low-voltage switchgear	24 (61)
5 kV switchgear	36 (91)
15 kV switchgear	36 (91)
Other equipment	Determine in the field

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Arc Flash Mitigation

Working Distance

Example: 4160 V switchgear bus
11 kA arcing fault
Trip time = 2.0 sec

<u>Working Distance</u>	<u>Incident Energy</u>
18"	49 cal/cm ²
24"	37 cal/cm ²
36"	25 cal/cm ²

Note: Depending on type of installation/voltage, the relationship between working distance and incident energy can be as high as a square function....(decreasing working distance in half can quadruple the incident energy ... $E \propto \text{Distance}^2$)

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Arc Flash Mitigation

Proper Maintenance

- Don't forget about maintenance....
 - Proper storage
 - Working heaters if required
 - Avoid leaving equipment energized without load. There is a misconception about energized equipment being heated up just from the voltage
 - Don't forget about the open tie breaker
 - Use maintenance testing diagnostic tools...

AND READ THE TEST REPORTS

References / Credits

- NFPA 70E – 2018 Handbook
- NEC
- OSHA 1910 Subpart S – Electrical
- <https://brainfiller.com/videos/2018-nfpa-70e-changes-video/>

Thank You.

Questions?

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