Selective Coordination and Arc Flash Safety Overview

IEEE – Central Tennessee

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Purpose and Learning Objectives

Purpose of this class is:

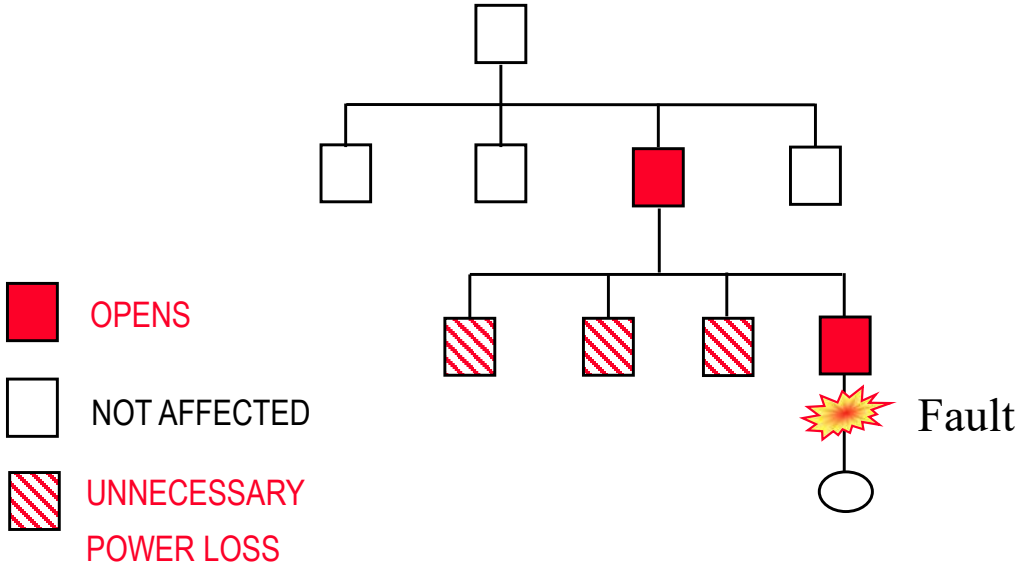
- To learn about Selective Coordination and provide an Arc Flash Safety Overview

At the end of this presentation, you will be able to:

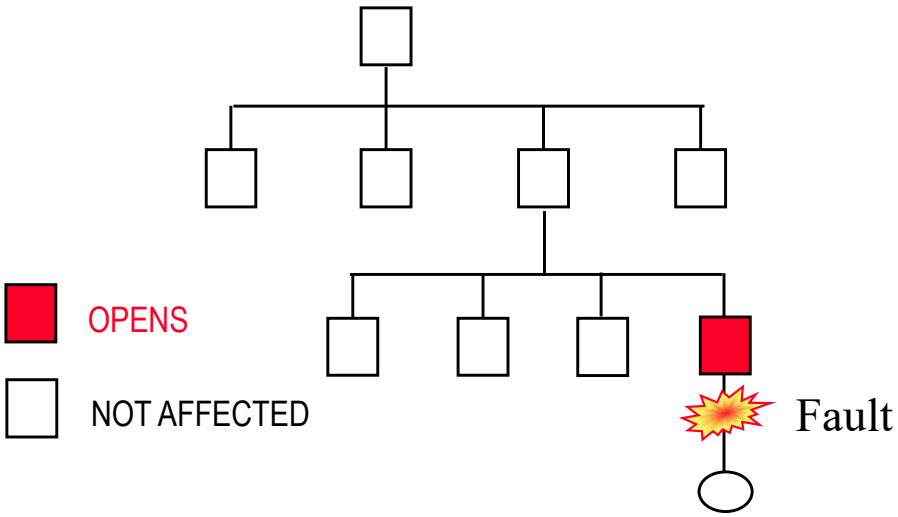
- Know what is Selective Coordination
- Arc Flash Safety and 4 strategies:
  - 1 – Reduce available fault current
  - 2 – Keep your distance
  - 3 – Redirect fault energy
  - 4 – Faster clearing time

What is Selective Coordination?

Without Selective Coordination

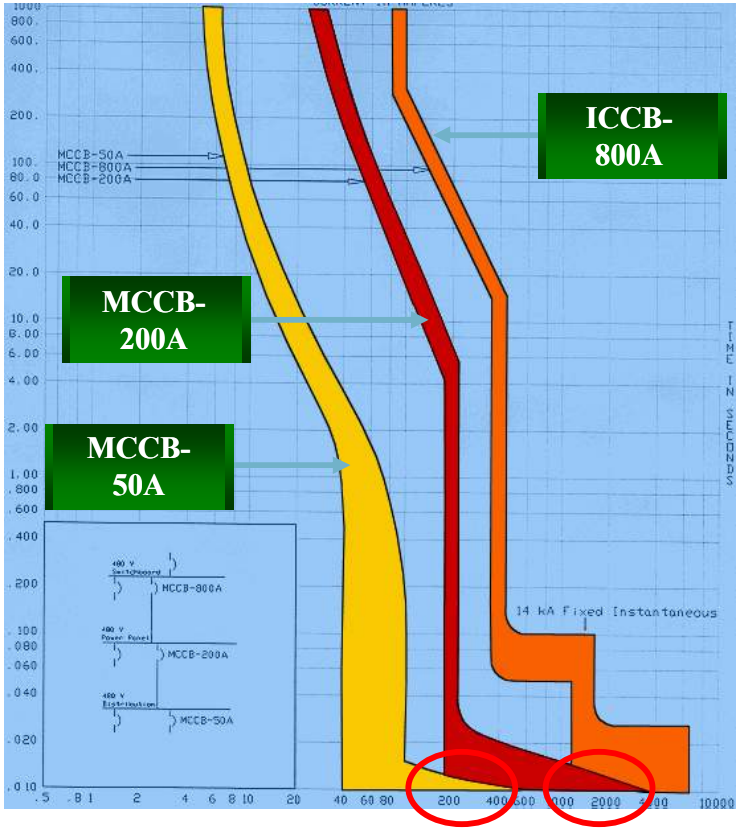


With Selective Coordination



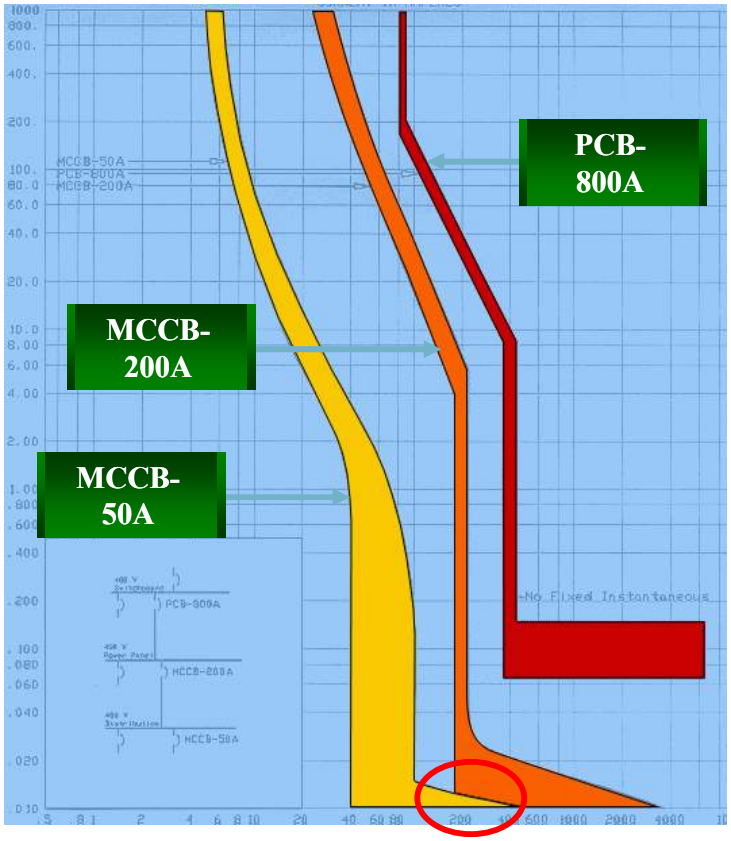
Localization of an overcurrent condition to restrict outages to only the circuit or equipment affected

Time Current Curve showing Selectivity of OCPD's



- High level of selectivity except for high magnitude faults
- Areas of overlap of the trip curves represent a theoretical lack of selectivity
- Faults of this magnitude may cause multiple OCPD's to operate

Time Current Curve showing Selectivity of OCPD's



- 800A breaker shows TOTAL selectivity with downstream devices
  - For all magnitudes of current, device takes longer to trip than downstream devices
  - aka "All currents. All times"
- 200A and 50A devices still have some overlap of the trip curves represent a theoretical lack of selectivity
- Faults of this magnitude may cause multiple OCPD's to operate

NEC Coordination Requirement – Health Care (Introduced in 2014 – remains same in 2017 / 2020 / 2023 NEC)

- **Coordination – Article 517.31 (G) Health Care Facilities**

  *(G) **Coordination**. Overcurrent protective devices serving the essential electrical system **shall be coordinated for the period of time that a fault's duration extends beyond 0.1 second.***

  Exception No. 1: Between transformer primary and secondary overcurrent protective devices, where only one overcurrent protective device or set of overcurrent protective devices exists on the transformer secondary

  Exception No. 2: Between overcurrent protective devices of the same size (ampere rating) in series.

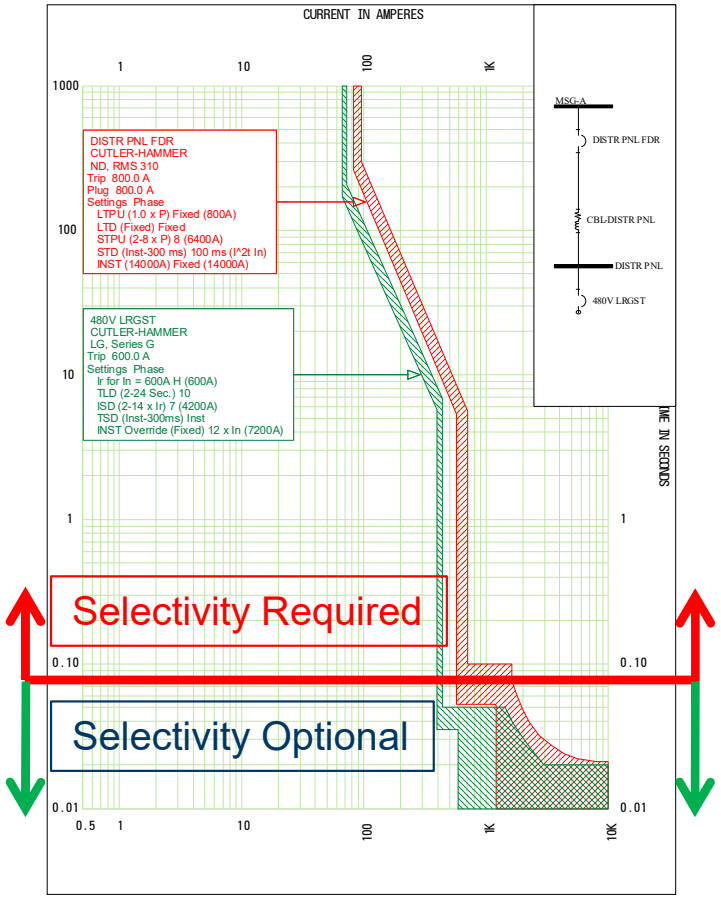
  Informational Note 1: The terms coordination and coordinated as used in this section do not cover the full range of overcurrent conditions.

  Informational Note 2: See 517.17(C) for information in requirements for the coordination of ground fault protection.

NEC introduced term "Coordination"
for Health Care Facilities / Extracted from NFPA 99 2012

0.1 Sec Coordination – Health Care

- Minimum level of selectivity required is above 0.1 sec
  - Added to NFPA 99 in 2012 and NEC in 2014
  - Consistent with decades of design practice in health care industry
  - Standards Council defined coordination as a *performance* requirement under NFPA 99 purview
  - Unlikely to change
- Allows overlap in the instantaneous region of OCPD's
- Engineer can make the decision of balancing protection and selectivity
- Nothing prohibits specifying a higher level of selectivity, if desired



NEC Selective Coordination Definition Change (Introduced in 2014 remains similar in 2017 / 2020 / 2023 NEC)

- **Coordination (Selective) - Article 100 Definitions**
  - Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the ***selection and installation*** of overcurrent protective devices and their ratings or settings ***for the full range of available overcurrents, from overload to the available fault current, and for the full range of overcurrent protective device opening times associated with those overcurrents.***

Selective Coordination Mandated in NEC

Indicates Major Change

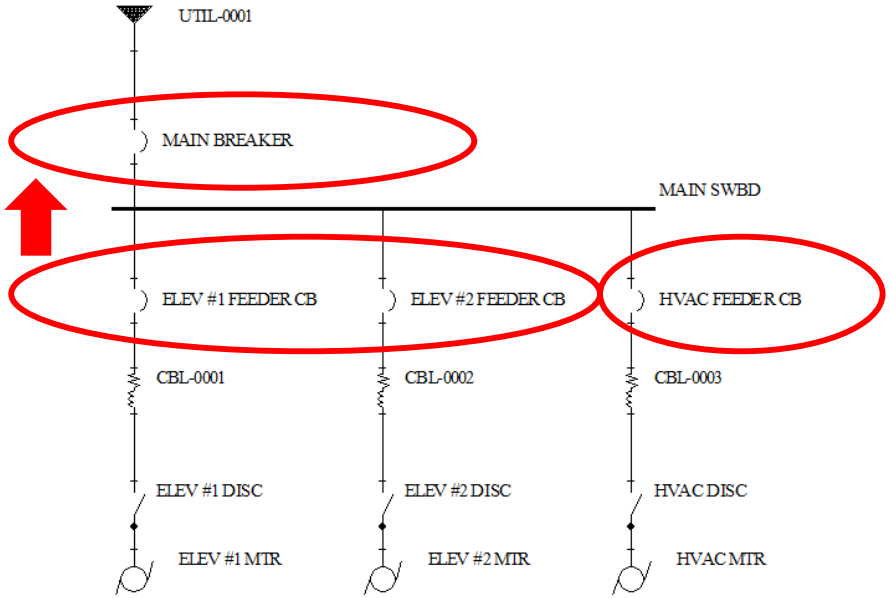
Art	Title	NEC VERSIONS								
		1993	1996	2005	2008	2011	2014	2017	2020	2023
100	*Definitions*			100	100	100	100	100	100	100
240	*Overcurrent Protection*									240.11
620	*Elevators, Dumbwaiters, Escalators, Moving Walks, Wheel Chair Lifts, and Stairway Chair Lifts*	620.51(a)	620.62	620.62	620.62	620.62	620.62	620.62	620.62	620.62
645	*Information Technology Equipment*						645.27	645.27	645.27	645.27
695	*Fire Pumps*					695.3(C)(3)	695.3(C)(3)	695.3(C)(3)	695.3(C)(3)	695.3(C)(3)
700	*Emergency Systems*			700.27	700.27	700.27	700.28	700.32	700.32 (added diagram)	700.32 (Added Replacements & Modifications)
701	*Legally Required Standby Systems*			701.18	701.18	701.18	701.27	701.32	701.32 (added diagram)	701.32 (Added Replacements & Modifications)
708	*Critical Operations Power Systems (COPS)*				708.54	708.54	708.54	708.54	708.54 (added diagram)	708.54 (Added Replacements & Modifications)

Most common areas requiring Selective Coordination

NEC Requirement – 240.11(2023)

If one or more feeder overcurrent protective devices are required to be selectively coordinated with a service overcurrent protective device by other requirements in the *Code*, all feeder overcurrent protective devices supplied directly by the service overcurrent protective device shall be selectively coordinated with the service overcurrent protective device.

Since NEC Article 620.62 requires the Elevator Feeder breakers to selectively coordinate with the Main Breaker in this example, then ALL feeder breakers on this incoming Switchboard lineup shall be selectively coordinated with the service overcurrent protective device (i.e., Main Breaker).



NEC Requirement (Introduced in 2014 – remains same in 2017 / 2020 / 2023 NEC)

- **Coordination (Selective) – Article 700.32, 701.32 and 708.54**
  - Added verbiage to new General section (A) in each of these articles: The word **load-side** was added in the 2023 addition to make it clear that selective coordination must be examined both upstream and downstream.
  - **General Section (A) Language:** Emergency, Legally Required, and Critical Operations OCPDs shall be selectively coordinated with all supply-side and load-side OCPS. Selective coordination shall be selected by a licensed professional engineer, or other qualified persons engaged primarily in the design, installation or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operation the system.

NEC clarified person responsible for system selection and improves the process for the AHJ and contractor

NEC Requirement (Introduced in 2014 – remains same in 2017 / 2020 / 2023 NEC)

- **Coordination (Selective) – Article 700.32, 701.32 and 708.54**
  - Added sections 700.32(A)/(B)/(C)
    - ***N (B) Replacements.*** *Where emergency system(s) OCPDs are replaced, they shall be reevaluated to ensure selective coordination is maintained with all supply-side and load-side OCPDs.*
    - ***N (C) Modifications.*** *If modifications, additions, or deletions to the emergency system(s) occur, selective coordination of the emergency system(s) OCPDs with all supply-side and load-side OCPDs shall be reevaluated.*
  - Added sections 701.32(B)/(C)
    - ***N (B) Replacements.*** *Where legally required system(s) OCPDs are replaced, they shall be reevaluated to ensure selective coordination is maintained with all supply-side and load-side OCPDs.*
    - ***N (C) Modifications.*** *If modifications, additions, or deletions to the legally required system(s) occur, selective coordination of the legally required system(s) OCPDs with all supply-side and load-side OCPDs shall be reevaluated.*
  - Added sections 708.54(B)/(C)
    - ***N (B) Replacements.*** *Where critical operations power system(s) OCPDs are replaced, they shall be reevaluated to ensure selective coordination is maintained with all supply-side and load-side OCPDs.*
    - ***N (C) Modifications.*** *If modifications, additions, or deletions to the critical operations power system(s) occur, selective coordination of the critical operations power system(s) OCPDs with all supply-side and load-side OCPDs shall be reevaluated.*

NEC clarified person responsible for system selection and improves the process for the AHJ and contractor

NEC Levels of Selective Coordination

Selective Coordination	All times and all currents

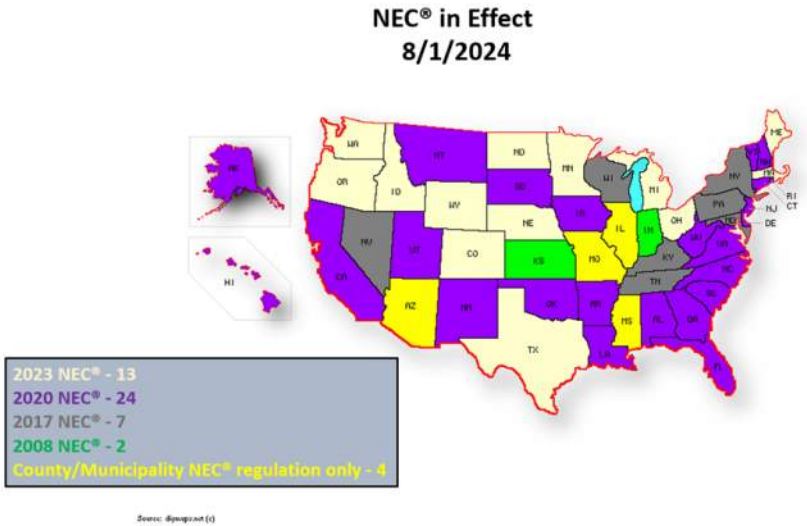
• Feeders – 240.11
• Elevators – 620.62
• Critical Operations Data Systems (CODS) – 645.27
• Multi-building Campus-Style Complexes (Fire Pumps) – 695.3(C)(3)
• Emergency Systems – 700.28
• Legally Required Standby Systems – 701.27
• (Critical Operations Power Systems (COPS) – 708.54
• (Critical Operations Power Systems (COPS) – 708.54 (2008 NEC®)
	• Complete system up-time is imperative for life safety or business continuity reasons
	  • Life Safety Systems – Egress / Communication in an emergency
	  • Legally Required Standby – Public safety risk
	  • Data / Information Technology
	  • Refrigeration required (i.e., Food Distribution)
	  • Continuous process systems (i.e., Chemical Plant)

0.1 Coordination (Healthcare)	**Separation of curves above 0.1 sec**
• Essential Electrical Systems for Hospitals Coordination – 517.31	• May not coordinate in case of high magnitude overcurrent events (very rare) • Continuity of supply addressed by other means in design process
Normal System	
▪ Selective Coordination or Coordination is not required by NEC unless required by 240.11	• Generally the most economical systems chosen • Fully rated & series rated circuit breakers are options • System designers have flexibility to the level of coordination they design into the system and therefore flexibility in choosing the components

Level of coordination is determined by local/national code requirements, and customer preference for system characteristics

NEC Adoption Varies by State

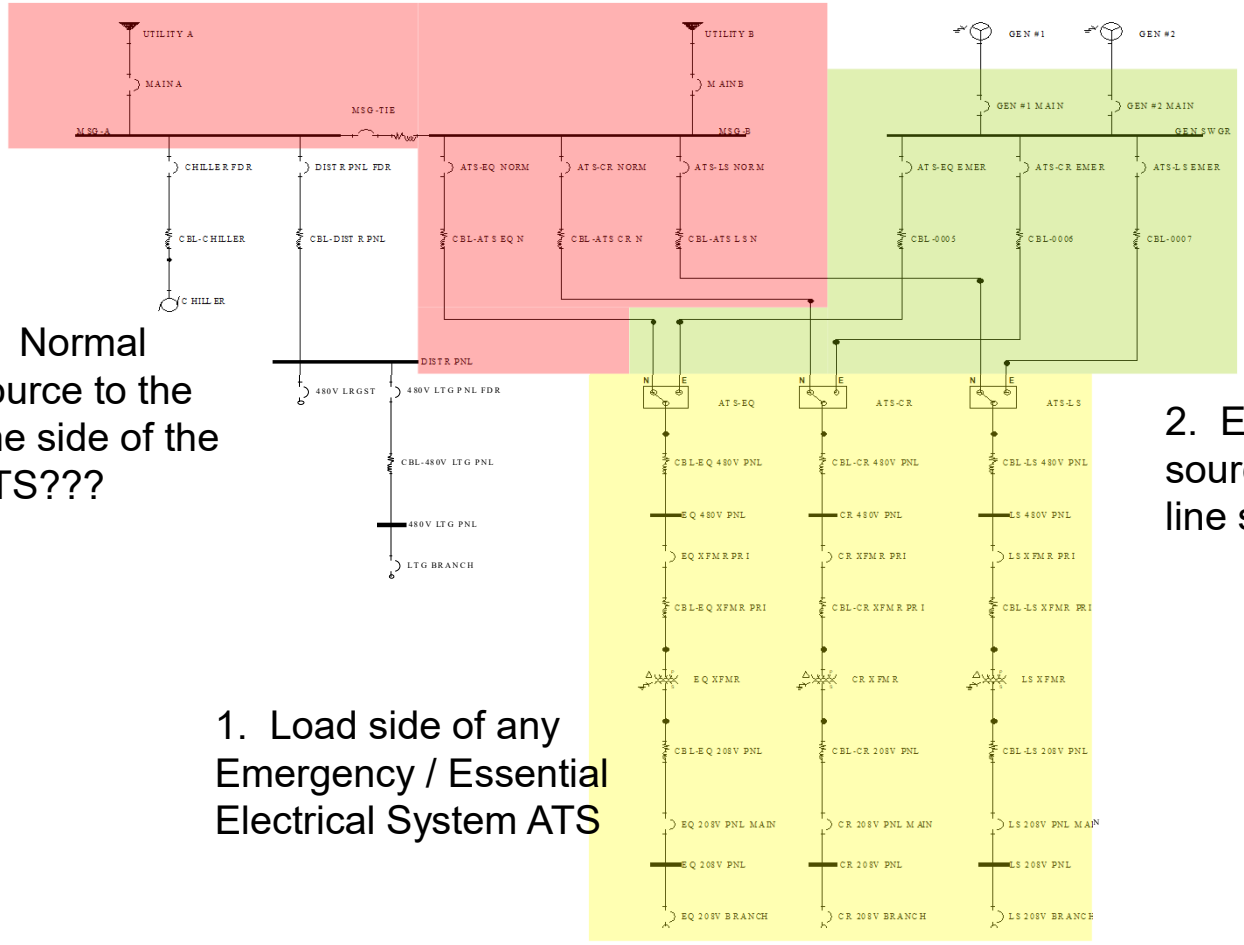
- How the code is enforced varies by jurisdiction
- Typical for AHJ to ask for a letter from the engineer of record stating compliance
- Interpretations vary widely



- *The 2022 California Electrical Code, California Code of Regulations Title 24, Part 3 is based on the 2020 edition of NFPA 70®, National Electrical Code®.*
- *The 2018 Chicago Electrical Code is based on the 2017 edition of NFPA 70®, National Electrical Code®*
- *The 2011 New York City Electrical Code is based on the 2008 edition of NFPA 70®, National Electrical Code®*

Code Adoption continually changes as more states adopt newer versions of the code. Use this link to go to the latest map.
https://www.nema.org/Technical/FieldReps/Documents/NEC-Adoption-Map.pdf

What devices are required to Selectively Coordinate?

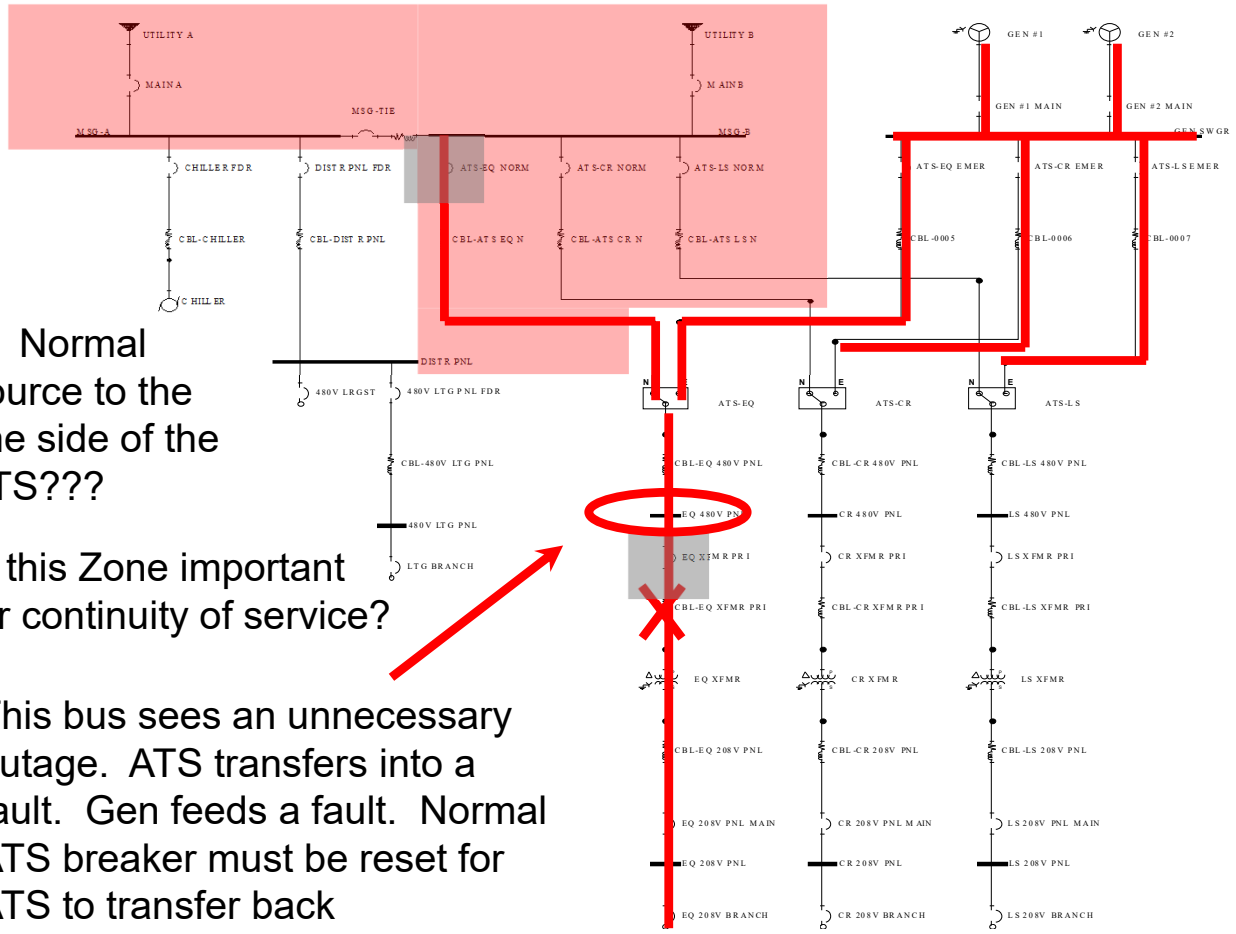


3. Normal source to the line side of the ATS???

2. Emergency source to the line side ATS

1. Load side of any Emergency / Essential Electrical System ATS

What devices are required to Selectively Coordinate?



3. Normal source to the line side of the ATS???

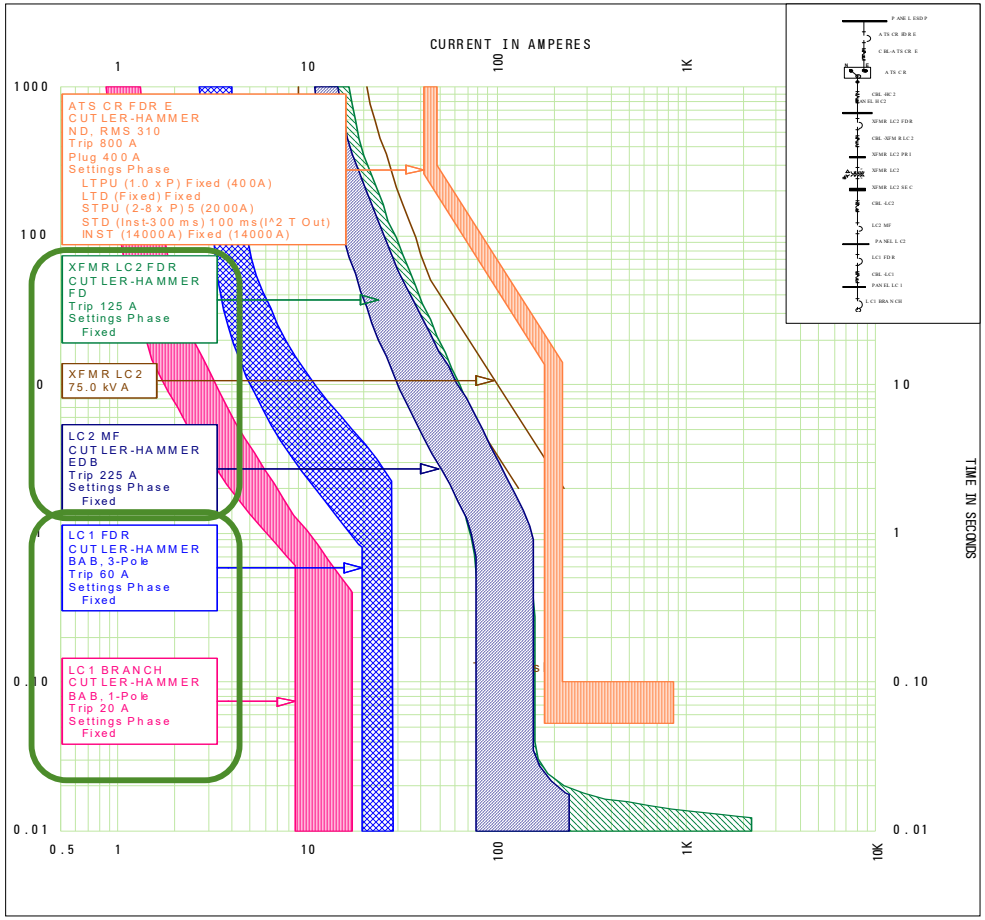
Is this Zone important for continuity of service?

This bus sees an unnecessary outage. ATS transfers into a fault. Gen feeds a fault. Normal ATS breaker must be reset for ATS to transfer back

Evaluating the Level of Selectivity (Coordination)

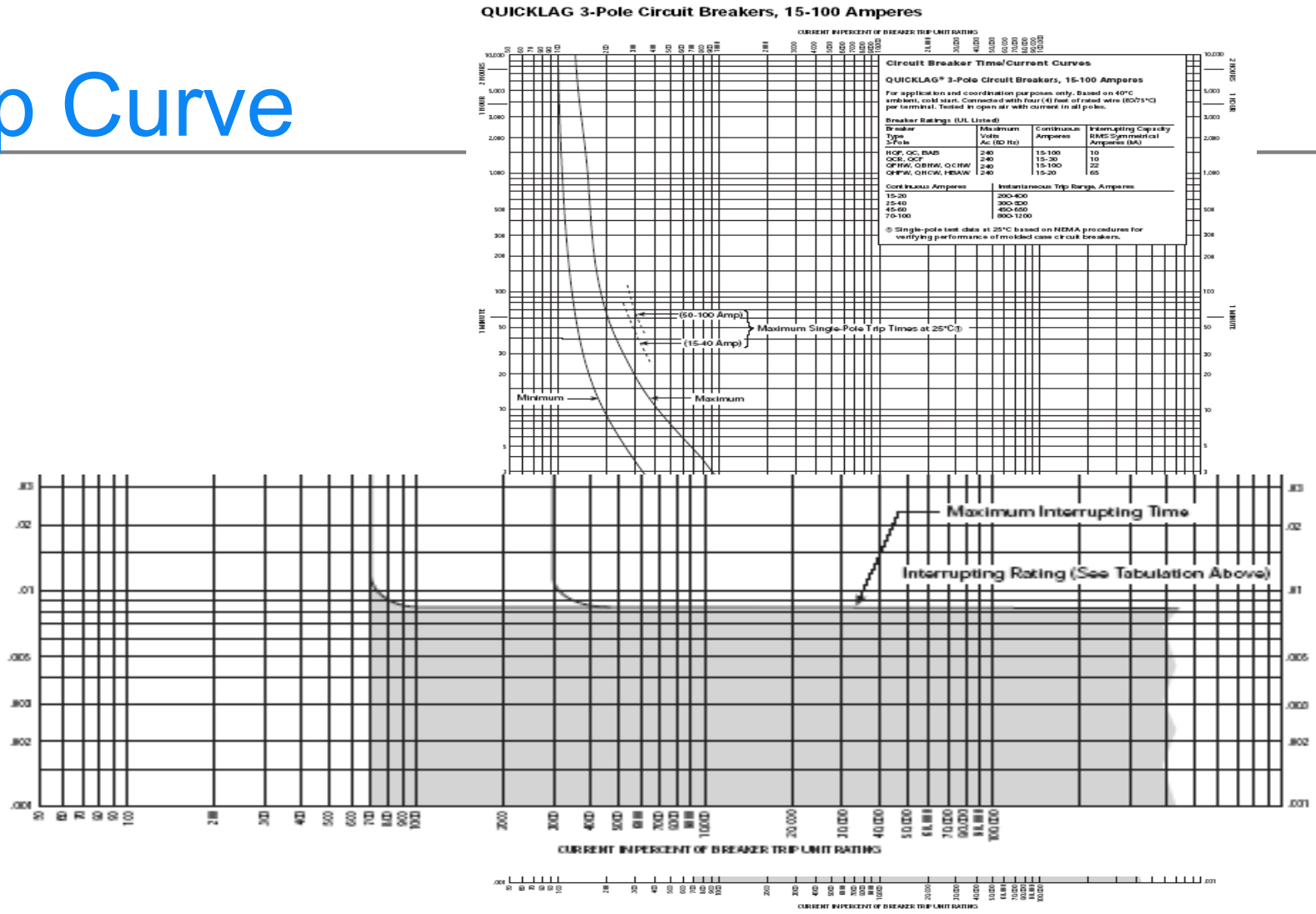
Time Illustration of Selective Coordination

- The drawing to the right is from the SKM Program
- Does this meet the NEC definition of “Selectively Coordinated”?
- Devices around transformer don’t have to be selective
- Look at the lowest system overcurrent devices
- Does the 20A BAB coordinate with the 60A BAB?
- This SKM chart cuts off at 0.01 sec.
- Have to look at breaker coordination charts

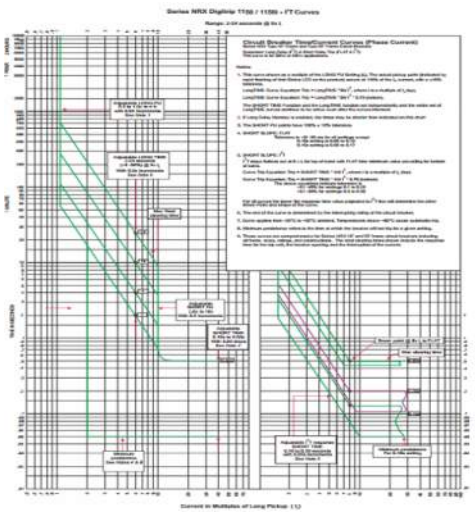


BAB Trip Curve

.01 Sec →



Time Current Curves, Software, and ‘Tested Pairs’



EasyPower

SKM Power Tools
ELECTRICAL ENGINEERING SOFTWARE

etap
Thinking Power

EDSA

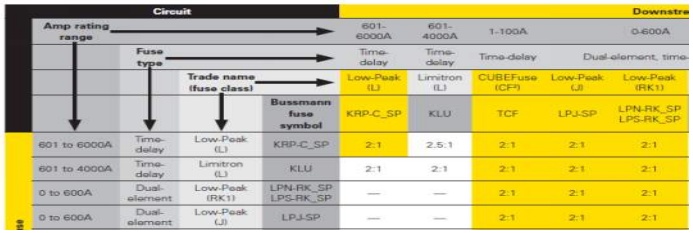


Table 9a MCCB to MCCB Selective Coordination Combinations—Test Data (All Values in kAIC rms Current Levels at 600 Vac) (continued)

Load Side Breaker	Breaker Family Type Trip Unit Minimum Trip Maximum Trip	Line Side Breaker (Standard and Current Limiting Frames) N ETU 400 A 400 A	N ETU 600 A 600 A	N ETU 320 A 800 A	N ETU 500 A 1200 A	R ETU 800 A 800 A	R ETU 1000 A 1000 A	R ETU 1200 A 1200 A	R ETU 800 A 1600 A	R ETU 1000 A 2000 A	R ETU 1600 A 2500 A
GHB/GHC Family (10 kA at 600Y/347 Vac)											
20		10	10	10	10	10	10	10	10	10	10
30		10	10	10	10	10	10	10	10	10	10
50		10	10	10	10	10	10	10	10	10	10
70		10	10	10	10	10	10	10	10	10	10
100		10	10	10	10	10	10	10	10	10	10
EG Family (25 kA at 600Y/347 Vac)											
15		25	25	25	25	25	25	25	25	25	25
30		25	25	25	25	25	25	25	25	25	25
50		25	25	25	25	25	25	25	25	25	25
60		25	25	25	25	25	25	25	25	25	25
100		25	25	25	25	25	25	25	25	25	25
125		25	25	25	25	25	25	25	25	25	25
EG Current Limiting Family (35 kA at 600Y/347 Vac)											
15		35	35	35	35	35	35	35	35	35	35
30		35	35	35	35	35	35	35	35	35	35
50		35	35	35	35	35	35	35	35	35	35
60		35	35	35	35	35	35	35	35	35	35
100		35	35	35	35	35	35	35	35	35	35
125		35	35	35	35	35	35	35	35	35	35

Circuit					Downstre
Amp rating range			601-6000A	601-4000A	1-100A	0-600A
Fuse type			Time-delay	Time-delay	Time-delay	Dual-element, time-
Trade name (fuse class)			Low-Peak (L)	Limitron (L)	CUBEFuse (CF)	Low-Peak (J)	Low-Peak (RK1)
		Bussmann fuse symbol	KRP-C_SP	KLU	TCF	LPJ-SP	LPN-RK_SP LPS-RK_SP
601 to 6000A	Time-delay	Low-Peak (L)	KRP-C_SP	2:1	2.5:1	2:1	2:1	2:1
601 to 4000A	Time-delay	Limitron (L)	KLU	2:1	2:1	2:1	2:1	2:1
0 to 600A	Dual-element	Low-Peak (RK1)	LPN-RK_SP LPS-RK_SP	—	—	2:1	2:1	2:1
0 to 600A	Dual-element	Low-Peak (J)	LPJ-SP	—	—	2:1	2:1	2:1

- Time over current curves stop at 0.01 second for most OCPDs
- Manufacturer Tested Pair Tables / Fuse Ratio Tables must be used for all times and all currents (i.e. Selectively Coordinated per NEC definition).
- NOTE: All tools are created based on individual manufacturer testing data

Evaluation - Key Take Away

- 0.1 sec Coordination

→ TCC's

  - Tables can be used for selection
  - If adjustable OCPD's, TCC's required to determine settings
  - Available fault current really doesn't affect coordination

- Coordination (Selective)
  - (i.e. 100% Selectively Coordinated)
  - "All currents, all times"

→ Manufacturer's Tables + TCC's

  - Tables must be used to determine selectivity in instantaneous region
  - Fault currents must be known at each bus
  - If adjustable OCPD's, TCC's required to determine settings

Eaton 0.1 Second Coordination Chart

0.1 Second coordination chart

UPSTREAM DEVICE

UPSTREAM DEVICE		100 A (150 A sensor)			125 A			150 A			175 A			200 A			225 A			250 A			400 A			600 A			800 A			1000 A	1200 A
INTERRUPTING RATING	Thermal mag or static trip (PXR 10, 20, 25)	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	T/M	PXR 10	PXR 20, 25	PXR 25	PXR 25
35 kAIC @ 480 V / 85 kAIC @ 240 V		PDG2_G	PDG2_G	PDG2_G	PDG2_G	PDG3_G	PDG2_G	PDG2_G	PDG2_G	PDG2_G	PDG3_G	PDG3_G	PDG3_G	PDG2_G	PDG2_G	PDG2_G	PDG2_G	PDG2_G	PDG2_G	PDG3_G	PDG3_G	PDG3_G	PDG3_G	PDG3_G	PDG3_G	PDG3_G	PDG3_G	PDG3_G	PDG4_G	PDG4_G	PDG4_G	PDG5_K	PDG5_K
50 kAIC @ 480 V / 85 kAIC @ 240 V																																
65 kAIC @ 480 V / 100 kAIC @ 240 V		PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG2_M	PDG3_M	PDG3_M	PDG3_M	PDG3_M	PDG3_M	PDG3_M	PDG3_M	PDG3_M	PDG3_M	PDG4_M	PDG4_M	PDG4_M	PDG5_M	PDG5_M
100 kAIC @ 480 V / 200 kAIC @ 240 V		PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG3_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG2_F	PDG3_F	PDG3_F	PDG3_F	PDG3_F	PDG3_F	PDG3_F	PDG3_F	PDG3_F	PDG3_F	PDG4_F	PDG4_F	PDG4_F	PDG5_F	PDG5_F
LARGEST DOWNSTREAM DEVICE																																
1-pole GHG (14 kAIC)	T/M	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
1-pole GHB (14 kAIC)/HGHB (25 kAIC)	T/M	20	60	60	20	60	60	20	60	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
3-pole GHB (14 kAIC)	T/M	20	60	60	20	60	60	20	60	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PDG2_* (225 A frame)	T/M	X	X	15	15	45	80	15	90	100	100	100	110	125	110	125	125	125	150	150	125	150	225	200	225	225	225	225	225	225	225	225	225
	PXR 10	60	X	90	80	100	100	100	100	125	125	150	150	150	150	175	150	150	200	200	200	225	225	225	225	225	225	225	225	225	225	225	225
	PXR 20, 25	80	X	90	80	110	110	125	125	125	150	150	150	150	175	175	200	200	200	225	225	225	225	225	225	225	225	225	225	225	225	225	225
PDG3_* (400 A / 600 A frames)	T/M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	100	225	125	200	400	300	400	600	400	400	600	600
	PXR 10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	225	200	225	200	300	350	500	450	500	600	600	600	600	600
	PXR 20, 25	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	225	225	225	250	350	350	500	500	500	600	600	600	600	600
PDG4_* (800 A frame)	T/M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	400	300	400	500	600
	PXR 10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	800	600	700	800	800
	PXR 20, 25	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	700	700	700	800	800
PDG5_* (1200 A frame)	PXR 20, 25	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	800	1000

TRANSFORMER kVA

TRANSFORMER kVA	15 (10 kAIC)	30 (10 kAIC)	45 (10 kAIC)	75 (10 kAIC)	112.5 (10 kAIC)	150 (22 kAIC)		225 (22 kAIC)	300 (22 kAIC)	500 (35 kAIC)
PRIMARY AMPS	10	30	54	90	135	181		270	361	601
Primary breaker amperage	30 A	60 A	80 A	150 A	250 A	300 A		400 A	600 A	800 A
SECONDARY AMPS	42	83	125	208	313	417		625	834	1388
Secondary main breaker	50 A or 60 A BAB	100 A BAB	150 A PDG2_F T/M	300 A PDG3_F T/M	400 A PDG3_F T/M	500 A PDG3_F T/M		800 A PDG4_G T/M	1200 A PDG5_K	1600 A PDG6_M
Panelboard type	PRL1X (10 kAIC)	PRL1X (10 kAIC)	PRL1X (10 kAIC)	PRL1X (10 kAIC)	PRL1X (10 kAIC)	PRL1X (22 kAIC)	PRL3X (22 kAIC)	PRL4X (22 kAIC)	PRL4X or SWBD (22 kAIC)	PRL3X SWBD (35 kAIC)
Largest feeder	20 A BAB	30 A BAB	60 A BAB	100 A BAB	100 A BAB	100 A GBHW	100 A GBHW 225 A PDG2_F T/M	225 A PDG2_F T/M 350 A PDG3_F T/M 600 A PDG3_G PXR10	225 A PDG2_F T/M 600 A PDG3_F T/M 800 A PDG4_G PXR 10 1000 A PDG5_K PXR20, 25	225 A PDG2_F T/M 600 A PDG3_F T/M 800 A PDG4_G T/M 1200 A PDG5_K PXR20, 25
Subfeed	None	None	None	150 A PDG2_F T/M 225 A PDG2_G PXR10	225 A PDG2_F T/M	225 A PDG2_F T/M 300 A PDG3_F T/M 400 A PDG3_G PXR10	300 A PDG3_F T/M 400 A PDG3_G PXR10	N/A (Same chassis as a switchboard)	N/A (Same chassis as a switchboard)	N/A

PD-2	PD-3	PD-4	PD-5	PD-6
FEATURES				
15 A – 225 A Up to 100 kAIC	100 A – 600 A Up to 100 kAIC	300 A – 800 A Up to 65 kAIC	320 A – 1200 A Up to 150 kAIC	800 A – 2500 A Up to 100 kAIC

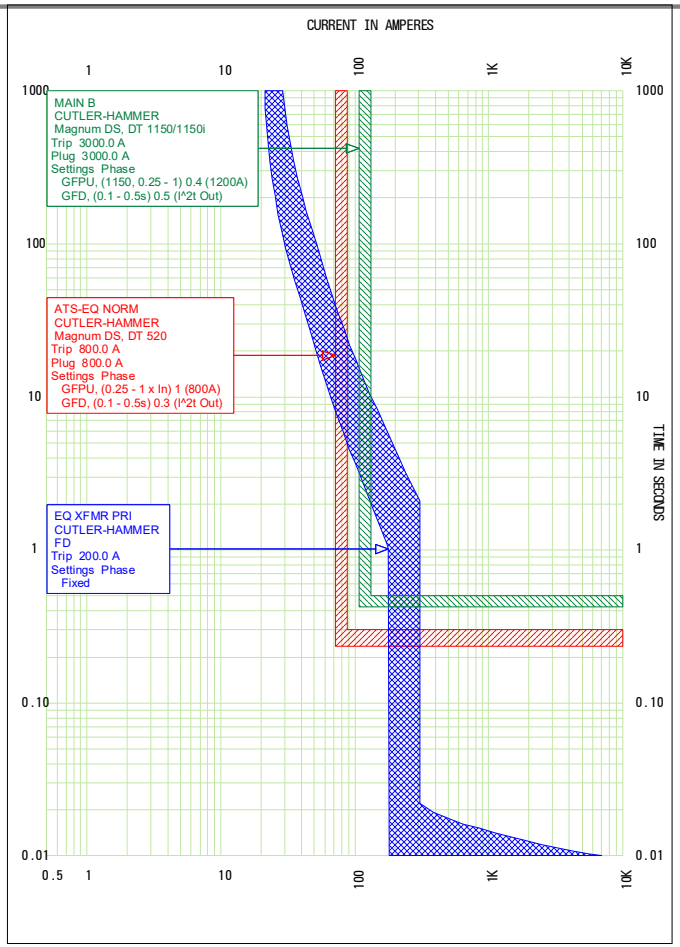
PXR ELECTRONIC TRIP UNIT FEATURES

PXR ELECTRONIC TRIP UNIT FEATURES	PXR 10	PXR 20	PXR 25
FEATURES			
Protection types	LSI	LSI / LSIG	LSI / LSIG
USB programming / testing	•	•	•
Cause-of-trip LEDs	Through USB	•	•
Load alarm – 2 levels		•	•
Breaker health and diagnostics		Through USB	•
Modbus® RTU communications		Opt	•
Programmable relays		Opt	•
Current metering		Through USB	•
Rotatable LCD display			•
Voltage, power, energy metering			•
Zone selective interlocking		Opt	Opt
Arcflash Reduction Maintenance System® maintenance mode		Opt (PD3 frame and larger)	Opt (PD3 frame and larger)

Don’t forget about Ground Fault!

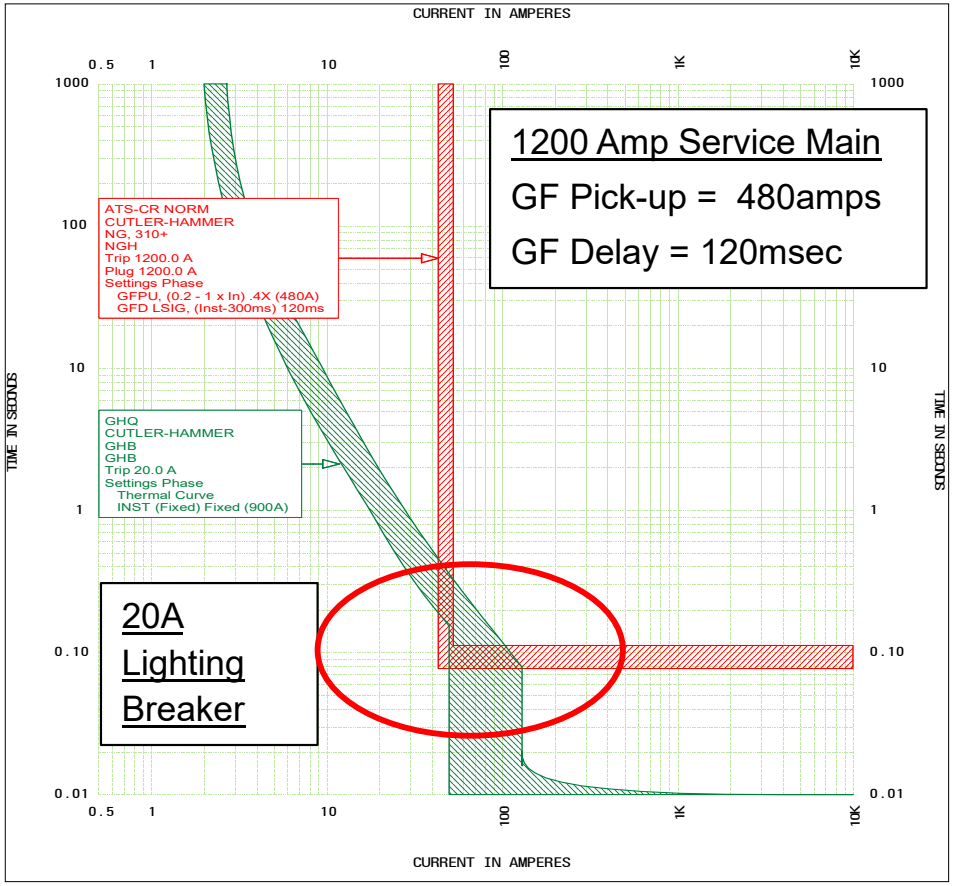
- GF Protection is required on Mains >=1000 amps on 480/277v systems
- What about coordination with required GF protection?
  - Max GF pick-up = 1200 Amps
  - Max GF delay = 0.5 – 1.0 sec
- Can cause coordination problems with downstream breakers of any size
- Healthcare applications require 2-levels of GF protection to address coordination issues
- Not addressed in the Code for other occupancy types

Highly recommend evaluating GF curves with a typical 480/277v branch circuits to ensure selectivity. Consider multiple levels of GF protection.



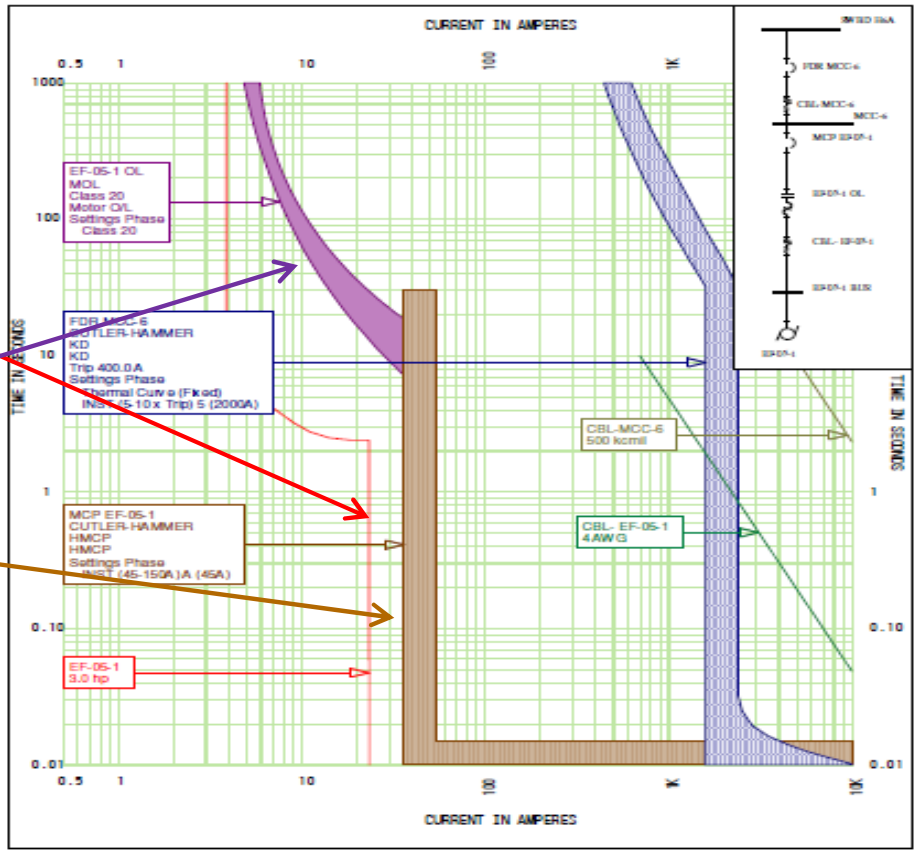
Don’t forget about Ground Fault!

- Make sure GF protection gets set during start-up!
  - Requires Engineer-of-Record to specify settings if a Coordination Study is not part of the contractor’s scope
- **ALL breakers are shipped with settings on minimum** (i.e. maximum protection)
- GF protection on the main will be more sensitive than downstream devices if not properly set
- Trips Main breaker of the entire facility
- Entire facility is tripped offline
- Makes it difficult to locate the actual fault location

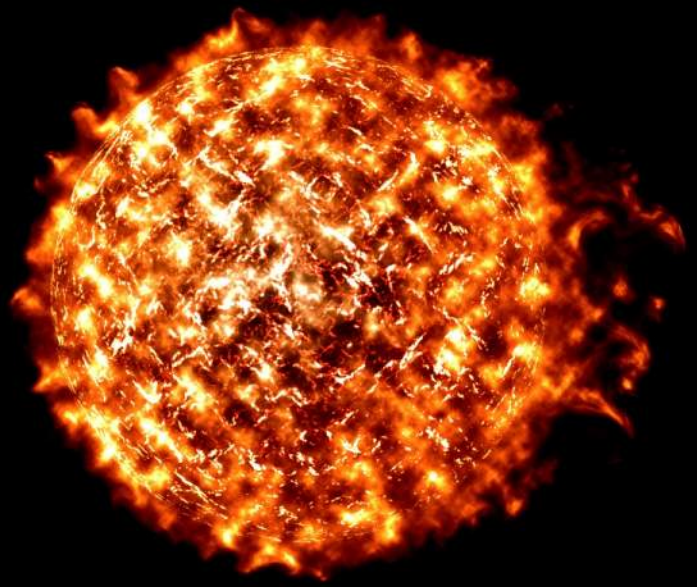


Motor Protection and Coordination

- Protective devices have to be coordinated with motor inrush
  - 6 – 10 times FLA
  - 2 – 10 seconds
- Overload relay provides protection from long overloads
- HMCP (Magnetic only circuit breaker) provides protection from high magnitude short circuits
  - Protection must be set higher than worst-case motor inrush

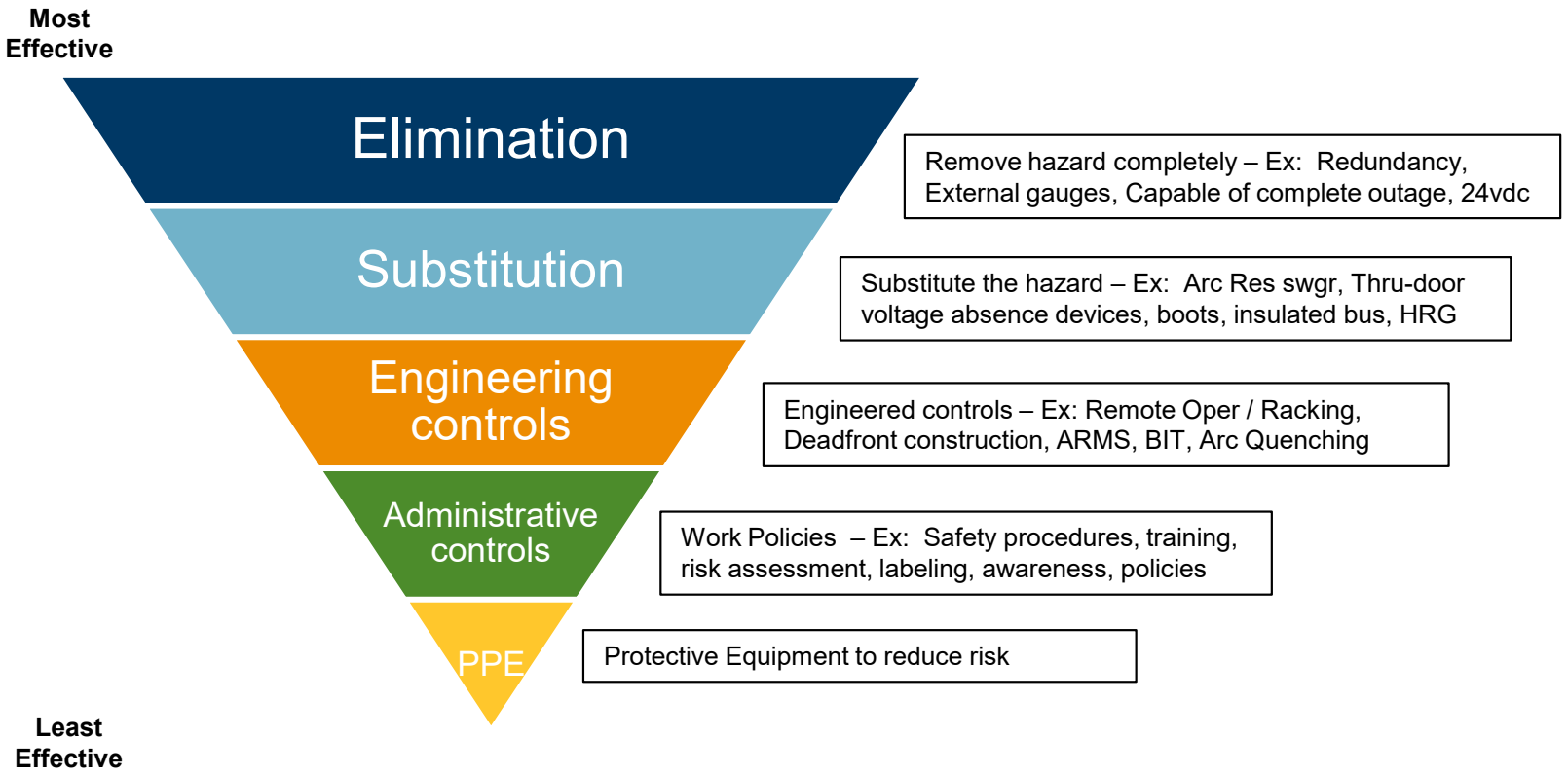


Arc Flash Safety Overview



Hierarchy of Risk Controls

(ANSI/AIHA Z10 – American National Standard for Occupational Health and Safety Management Systems)



Hierarchy of Risk Controls

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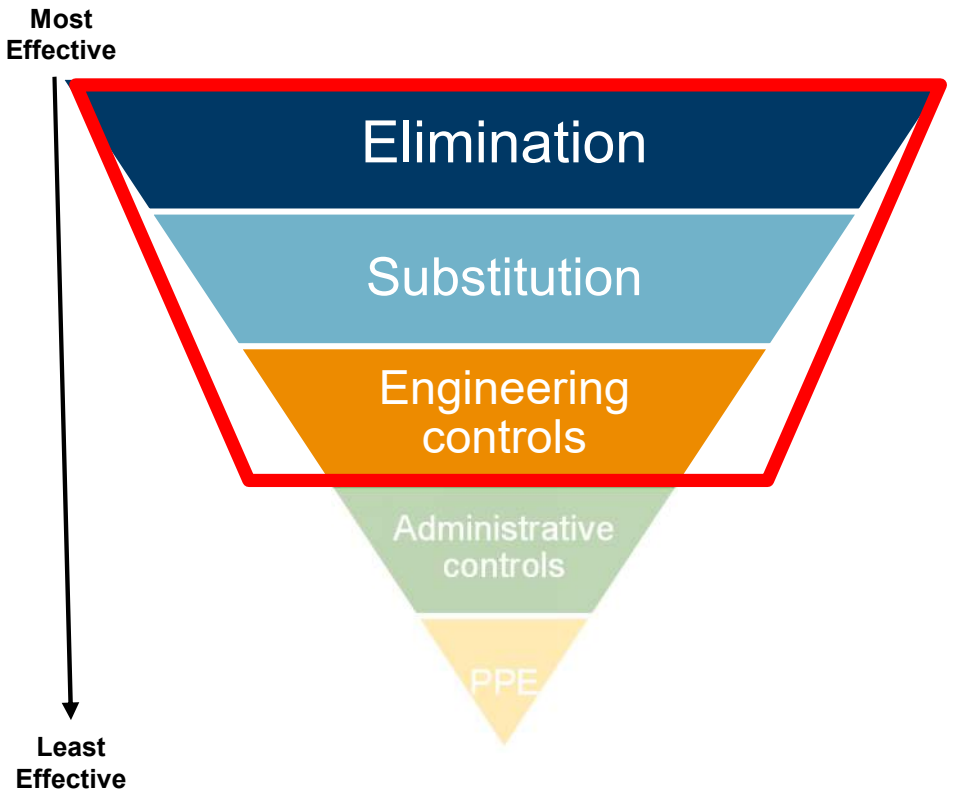
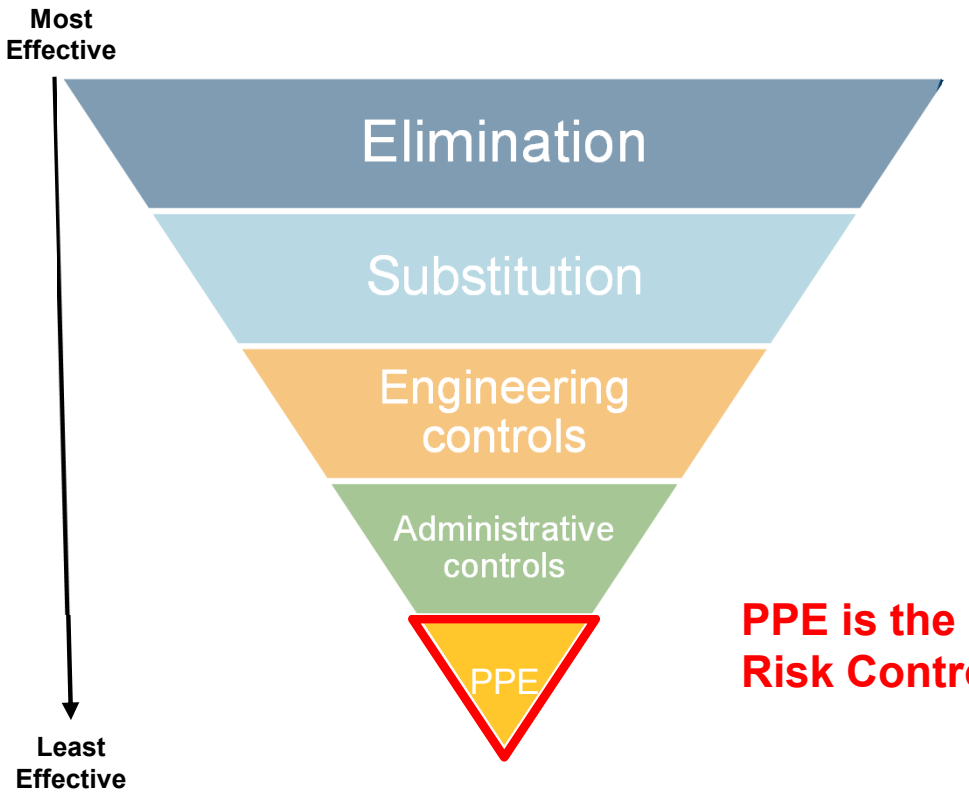


Risk Controls affected by distribution system <u>Design</u>

Hierarchy of Risk Controls

(ANSI/AIHA Z10 – American National Standard for Occupational Health and Safety Management Systems)



PPE is the least effective Risk Control method

Unless…

PPE = Pink Personal Equipment

Arc Flash Safety

- On average, only 1 out of every 500 workplace accidents involve electricity (0.2%)
- However, 1 out of every 45 work related fatalities involve electricity (2.2%)

This underlines the need for strong emphasis on Electrical Safety

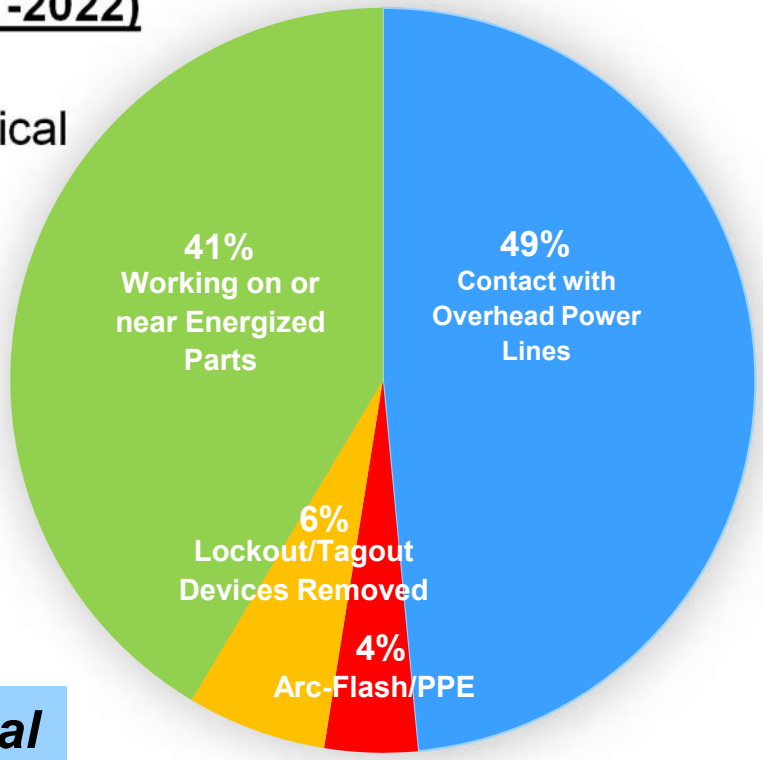
Numerous Codes and Standard changes have been made in the area of Arc Flash Safety

Arc Flash Safety

Workplace Electrical Fatalities as Reported to OSHA (2011-2022)

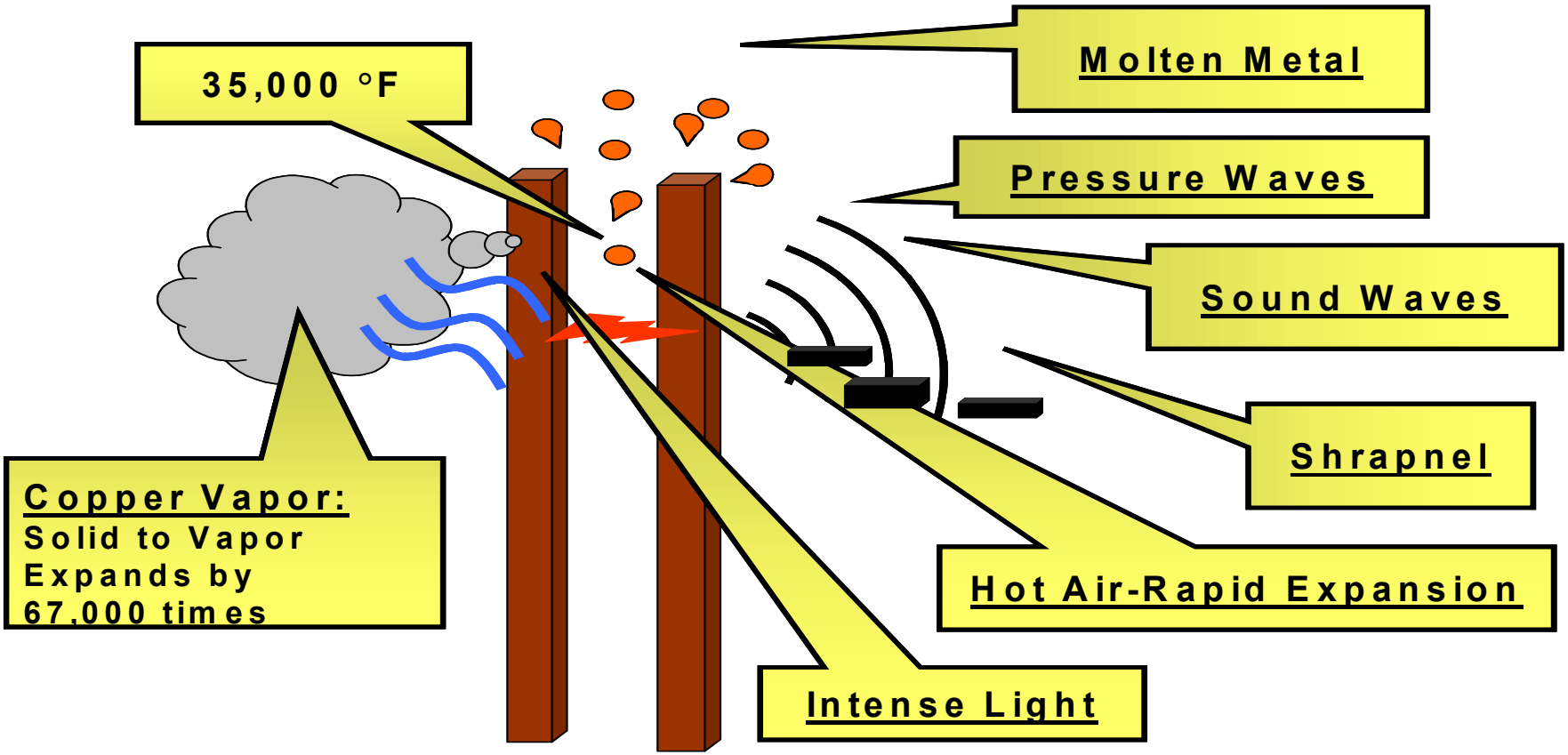
- **1322** workplace fatalities involving electricity.
- **70%** of workplace electrical fatalities occurred in non-electrical occupations.
- **6%** of all fatalities were caused by contact with electricity.
- Occupations with the Most Electrical Fatalities
  - Electricians: 195
  - Construction Laborers: 119
  - Laborers, Except Construction: 117
  - Electrical Power Installers & Repairers: 109
  - Tree Trimming Occupations: 94
  - HVAC & Refrigeration Mechanics: 42
  - Electricians' Apprentices: 37
  - Truck Drivers, Heavy: 35

1.5% average decrease in workplace electrical fatalities year over year since 2011 to 2022.



Electrical Fatality Causes as Reported to OSHA (2011-2022)

Why is an arc a hazard?



Factors affecting Arc Flash **Risk** evaluation

Incident Energy is a measure of the amount of energy released during an electrical arc event. It is used to estimate the extend of skin damage that would occur. Incident Energy is determined by the following factors:

1. **Available Fault Current** feeding the arc
2. **Distance** of the worker from the arc origin
3. **Clearing Time** – duration of the arc exposure

Total Clearing Time = Detection Time + Breaker Operation Time

1.2 cal/cm² exposure limits skin burn to 2nd degree (skin will regenerate)

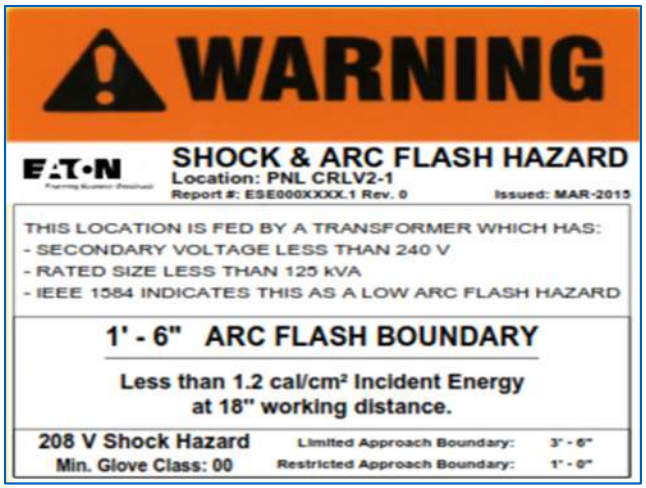
Need a Total System Approach to most effectively reduce Arc Flash **Risk**

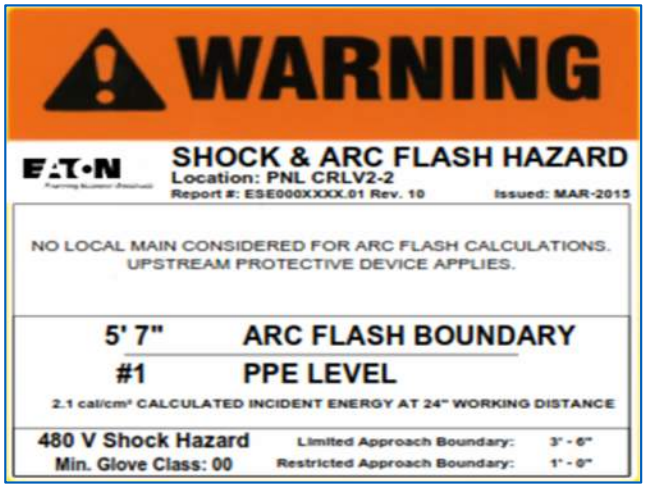
- Label Equipment
- Train Personnel on proper safety practices
- Reduce available fault current
- Redirect blast energy
- Faster clearing time
- Move people farther away
- Minimize the probability of faults occurring

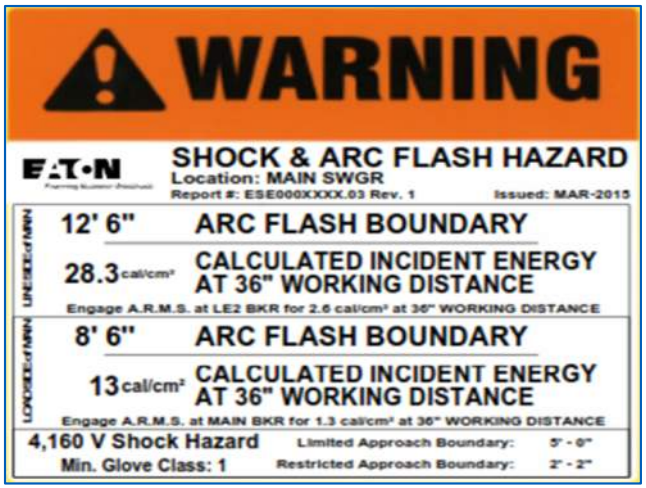
Reduce both **likelihood** and **severity**

De-Energize and lockout the circuits prior to working on equipment!

Sample Arc Flash Labels







- Information is not intuitive!
- Without proper training, crucial safety information on the labels will be ignored
- Workers may not be dressed in the appropriate PPE (Personal Protective Equipment) to keep from serious injury

It is very important that you understand how to interpret labeling

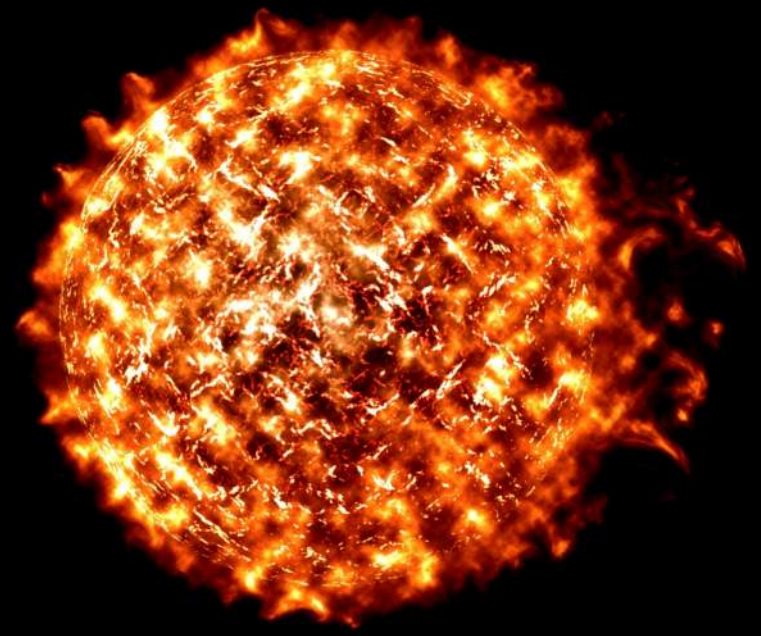
Factors affecting Arc Flash Risk evaluation

Skin damage will occur based on the intensity of the heat generated by an electrical arc accident. The heat reaching the skin of the worker is dependent on the following three factors:

1. **Power** (intensity) of the arc at its origin
2. **Distance** of the worker from the arc origin
3. **Time** duration of the arc exposure

1.2 cal/cm^2 exposure limits skin burn to 2nd degree (skin will regenerate)

Strategy #1: Reduce Available Fault Current



Reduce the Available Fault Current

- Know the available fault current
- NEC 110.16 (A) and (B), for short circuit current labeling

$$I_{SC} = I_{FL} \cdot \frac{1}{Z_{pu}}$$

$$I_{SC} = \frac{kVA}{\sqrt{3} \cdot kV \cdot \%Z}$$

Easily calculate available fault current anytime, anywhere

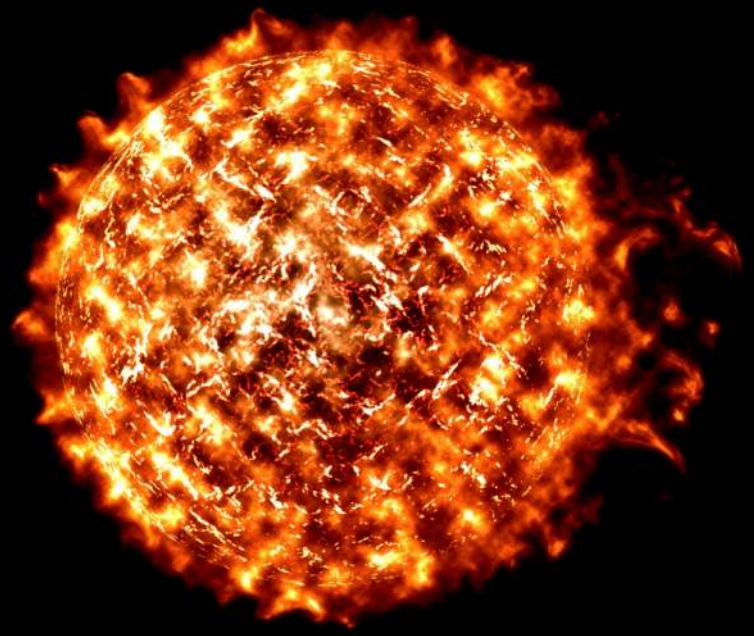
EATON BUSSMANN SERIES FC²

FC² Mobile App Quickly Delivers Fault Current Calculations in the Palm of Your Hand

Scan QR Code to download mobile app, open tab below for web-based version

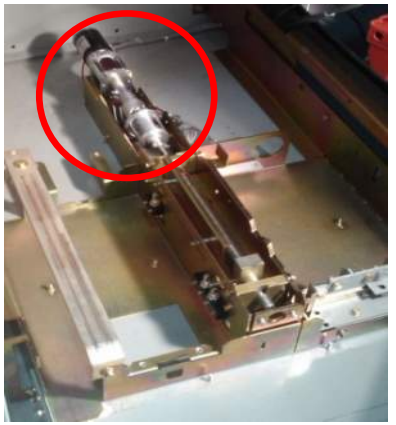
Rule of Thumb: Available Fault Current from a transformer with a 5% impedance is approximately 20 times the FLA.

Strategy #2:
Keep Your Distance



Options for keeping personnel outside of the Arc Flash Boundary

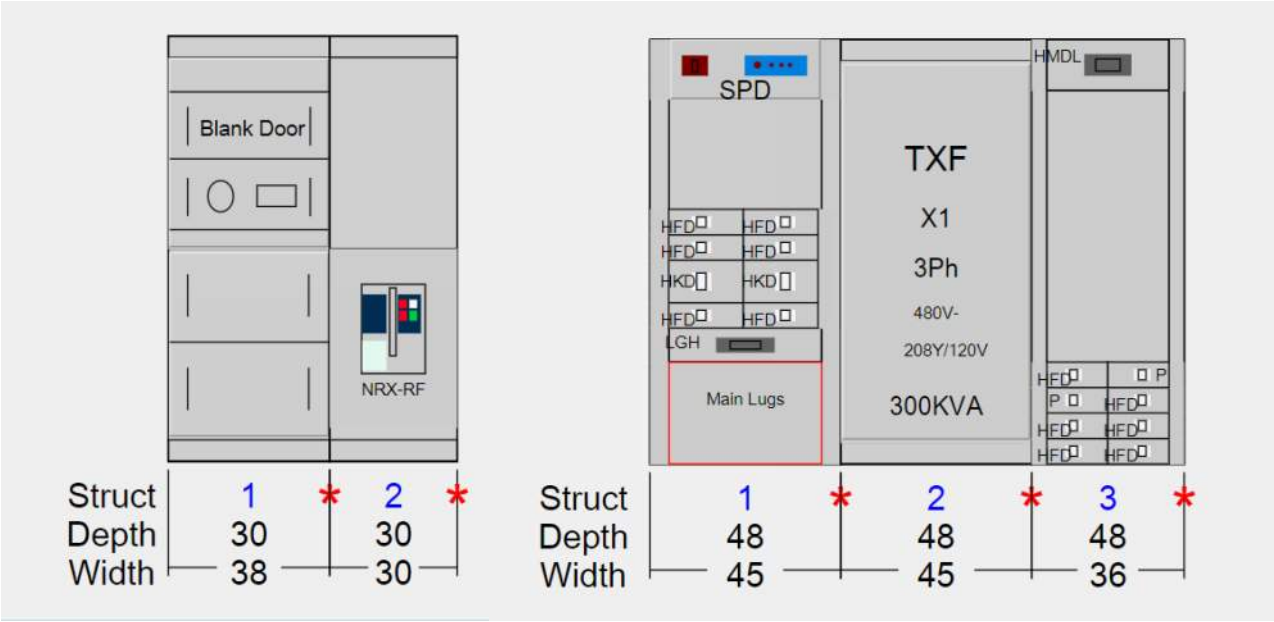
1. Remote Breaker Operation
2. Remote or Integral Racking
3. Electrically Operated Breaker



examples

Reduce your exposure

- Physically separate the Main in distribution systems
  - Eliminate exposure to line side energy levels, maintenance mode, remote operation



The safest safety switches

Double Door Switch

- Provides isolation from dangerous line side voltage

OLI (Control Panel) Switch

- Provides isolation from dangerous line side voltage in control panel applications

examples

Shield the operator with closed doors/panels

- Inspection Windows:
  - Infrared (IR) scanning
  - Visible inspection windows
  - Ultrasonic (US) ports

examples

Typical Padmount Transformer Gauge / Valve locations

Addressing Arc Flash

Externally operated visible break switch

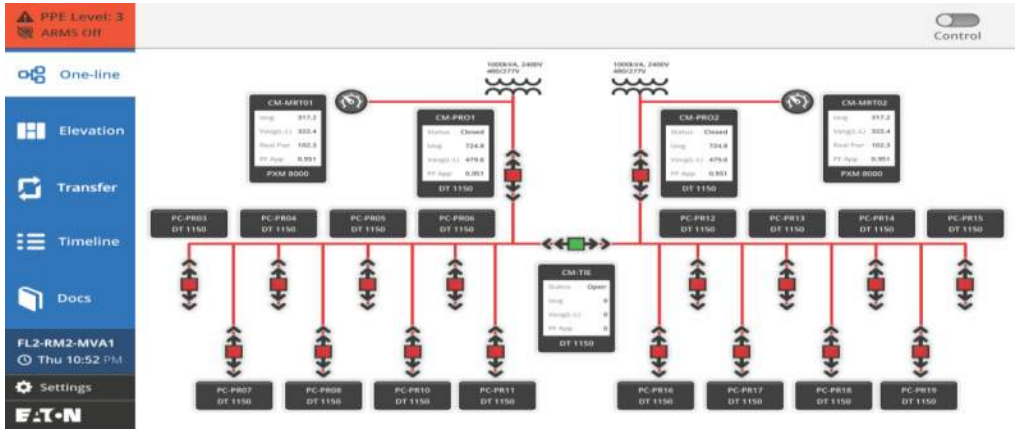
- No reason to enter cable compartment
- Ability to ground transformer power cables

External Gauges

- Gauges with optional alarm contacts, optional pressure accessories and optional heater
- Drain Valve & Sampler
- Load break switches

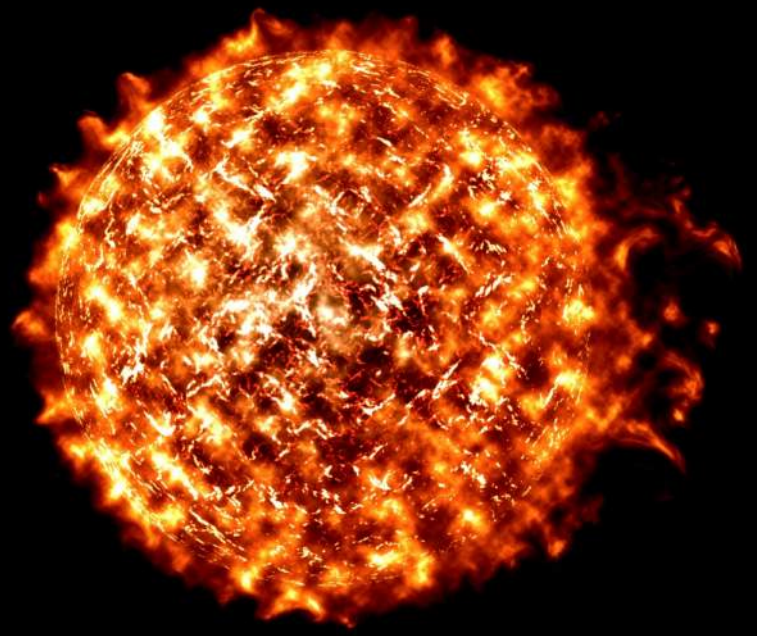
examples

Options for keeping workers outside of Arc Flash Boundary



examples

Strategy #3: Redirect Fault Energy – ANSI / IEEE Arc Resistant Switchgear



Examples of Arc Resistant Assemblies

MV Motor Control and Drives

MV Switches and Assemblies

LV Motor Control Centers

LV Metal-Enclosed Switchgear

examples

Arc Resistant Switchgear - Testing

- Figure #1 – Baseline test @ 65kA with arc initiated in bus compartment.
- Figure #2 – Arc initiated in Arc Resistant Gear. Blast directed to plenum.

Fig #1 - 65kA Bus Compartment Arc

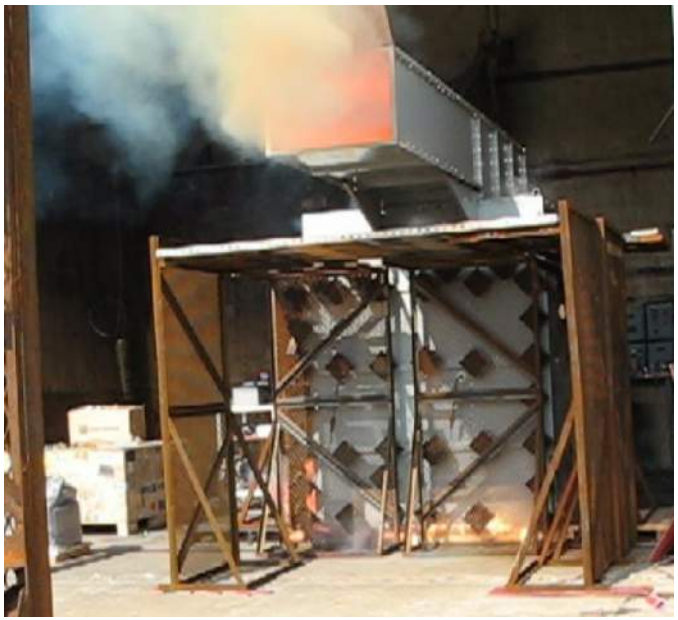


Fig #2 - 65kA in Arc Resistant Gear

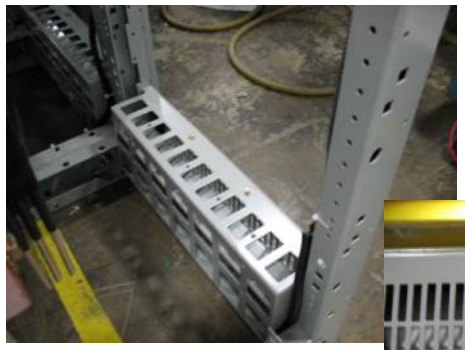
Arc Resistant metal-clad switchgear

examples

Traditional Arc-Resistant Switchgear

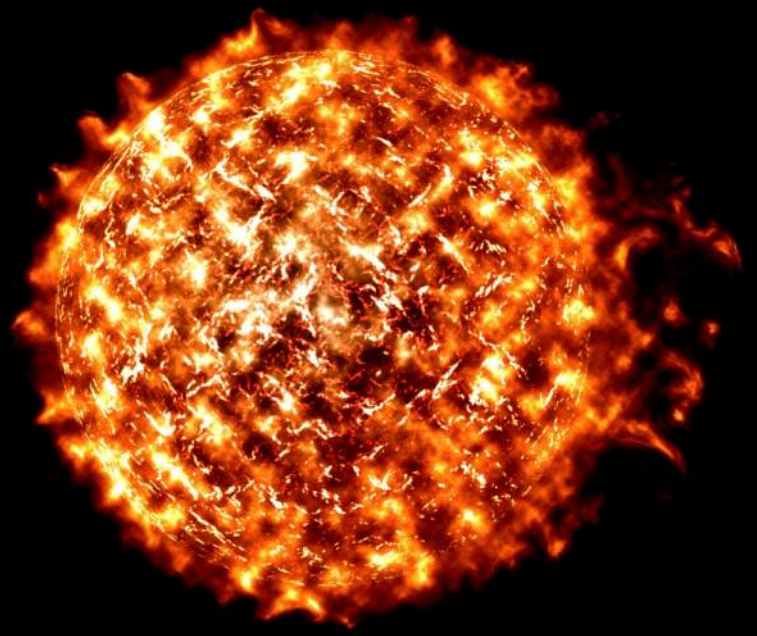
(Passive protection)

- LIMITATION: Arc-resistant switchgear doesn't protect equipment from damage and therefore does nothing to minimize downtime. Only effective when doors are closed and latched, covers on, etc.
- SOLUTION: Reduce the incident energy from an arc flash to a level where the equipment will survive an arc flash and can be rated as arc-resistant regardless of whether doors are open, covers / breakers removed, etc.



examples

Strategy #4: Faster Clearing Time



NEC requirement aimed at reducing arc flash risk

240.87 Arc Energy Reduction

ALL circuit breakers greater than or equal to 1200 A will now require:

"A Method to Reduce Clearing Time. One of the following or approved equivalent means shall be provided:

(1) Zone-selective interlocking or

(2) Differential relaying or

(3) Energy-reducing maintenance switching with local status indicator or

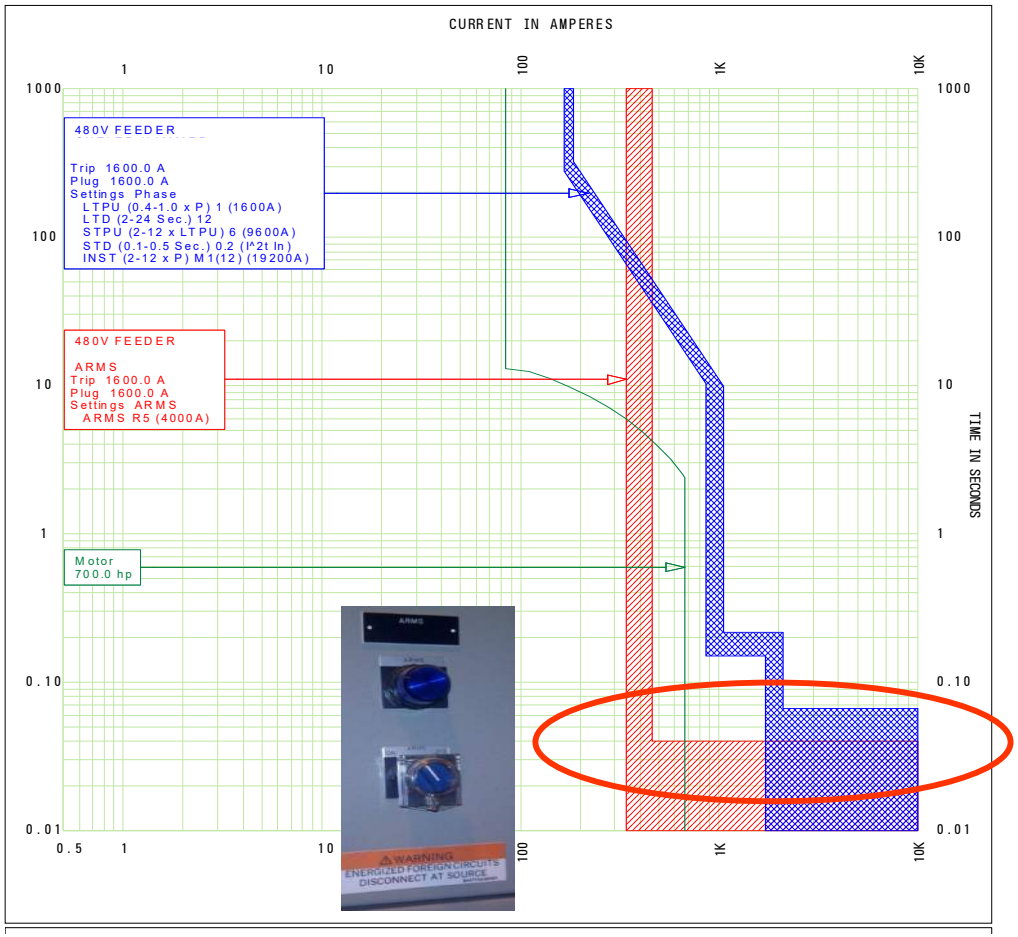
(4) Energy-reducing active arc flash mitigation system or

(5) An approved equivalent means"

Doesn't quantify any required level of reduction.

"Energy-reducing maintenance switching" methods are the most economical solution, but all solutions are not created equally…

Arcflash Reduction Maintenance System (ARMS)

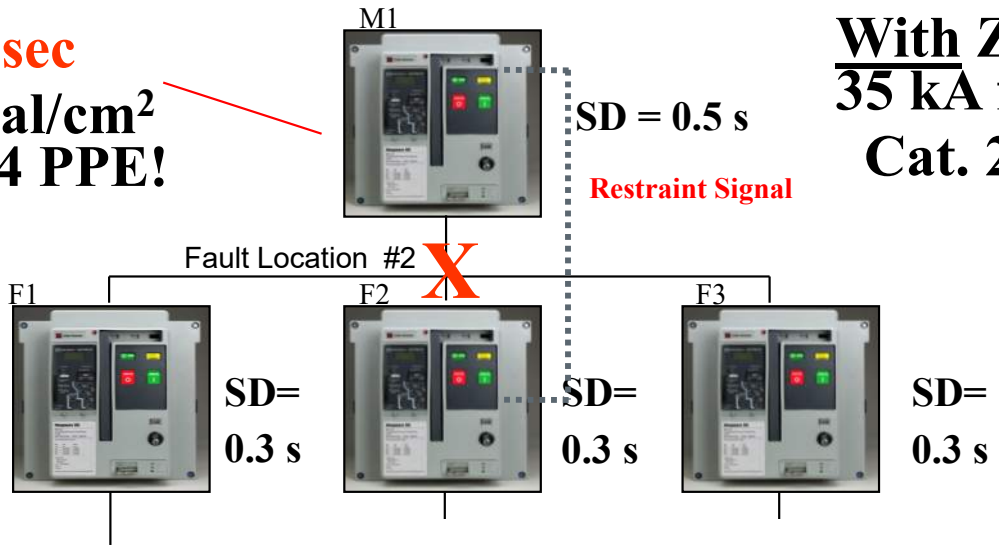


- When activated, pick-up setting and total breaker clearing time are reduced
- Eaton's ARMS Maintenance mode protection is ***"faster than instantaneous"***
  - Bypasses all microprocessor delays
- Total clearing time:
  - 40 msec - LV Power Breakers or MV breakers
  - 30 msec – MCCB Breakers
- Normal settings – 10.7 cal/cm^2
- **With ARMS enabled – 2.2 cal/cm^2**

Some manufacturer's "maintenance modes" are slower than normal instantaneous tripping (ZSI based) providing limited or no arc flash energy reduction.

Zone Selective Interlocking

Without ZSI = 0.5 sec
35 kA fault, 43.7 Cal/cm^2
Greater than Cat. 4 PPE!



With ZSI = 0.08 sec
35 kA fault, 7.0 Cal/cm^2
Cat. 2 PPE

NOTE: There is some time delay with ZSI to allow the upstream device to wait for a restraint signal from a downstream device. Much slower than ARMS or Bus Differential protection. (NOTE: This is the basis of some manufacturer's maintenance systems.)

Low Voltage Dry Type Distribution Transformers

480 -> 120/208Vac Xfmr

10 feet max

120/208Vac Panel

Higher incident energy than most people think

	cal/cm^2
45kVA Panel	6.67
75kVA Panel	11.60
112.5kVA Panel	14.80
150kVA Panel	26.38
225kVA Panel	32.39
300kVA Panel	42.07

Anything larger than 45kVA exceeds the 8cal/cm^2 clothing worn by most qualified maintenance personnel

examples

Low Voltage Dry Type Distribution Transformers- Breaker Integrated into Transformer (BIT)

- Secondary protection is integrated into transformer enclosure
- Adds nothing to transformer footprint. Only adds additional height
- Secondary panel becomes Main Lugs Only (MLO)
- Secondary panel can now be located anywhere. Not restricted to 10 feet from the transformer
- Has no effect on the incident energy calculation for the transformer

examples

Low Voltage Dry Type Distribution Transformers

10 feet max

	cal/cm^2
45kVA Panel	6.67
75kVA Panel	11.60
112.5kVA Panel	14.80
150kVA Panel	26.38
225kVA Panel	32.39
300kVA Panel	42.07

No distance restriction

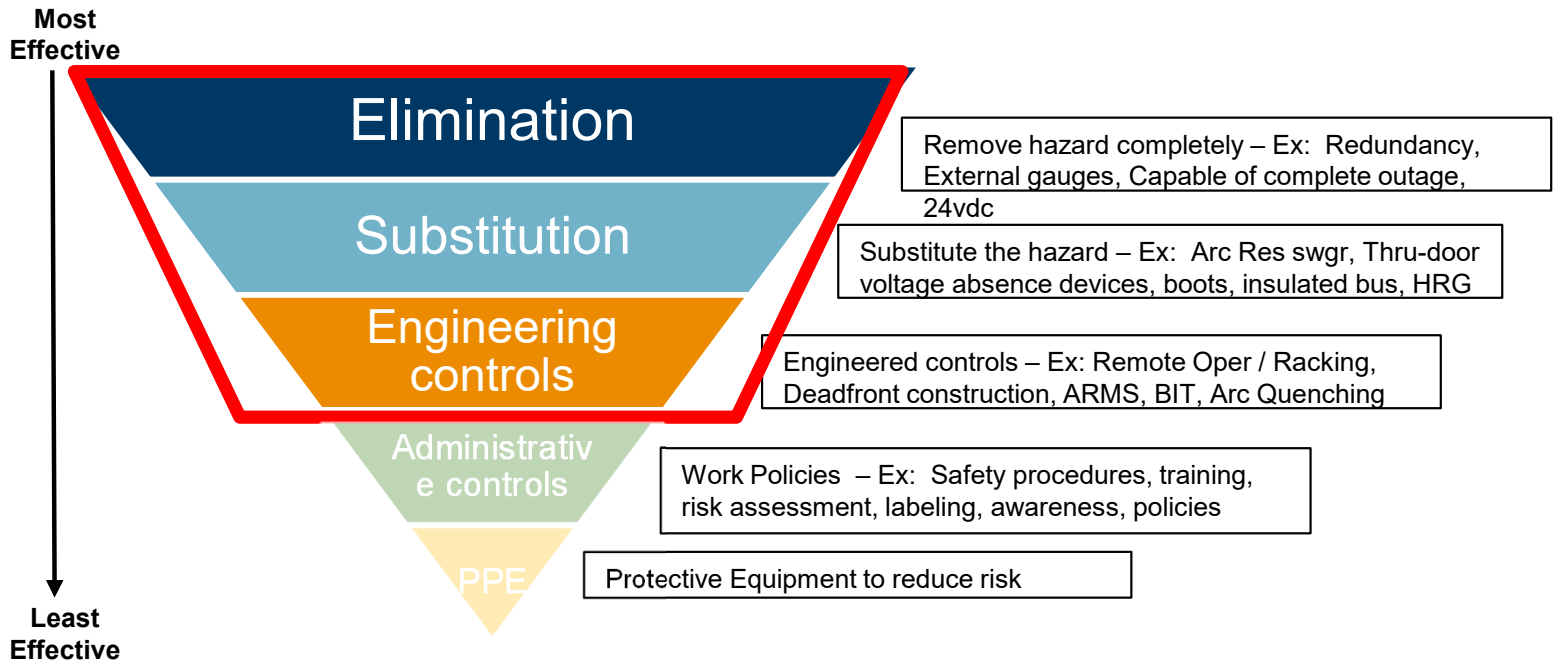
	cal/cm^2
45kVA BIT Panel	0.10
75kVA BIT Panel	0.17
112.5kVA BIT Panel	0.38
150kVA BIT Panel	0.65
225kVA BIT Panel	0.67
300kVA BIT Panel	1.05

Engineering controls

examples

Summary

- The design of substations and transformer systems has the greatest effect on reducing arc flash hazards
- Careful consideration and analysis of all available “tools” will result in distribution systems that are *“Safer By Design”!*



Questions?


Powering Business Worldwide