Arc Flash Standards and Arc Flash Risk Reduction Technologies

Solutions that reduce arc flash injuries and equipment damage

Bob Yanniello
VP of Engineering
Electrical Systems & Services
Eaton

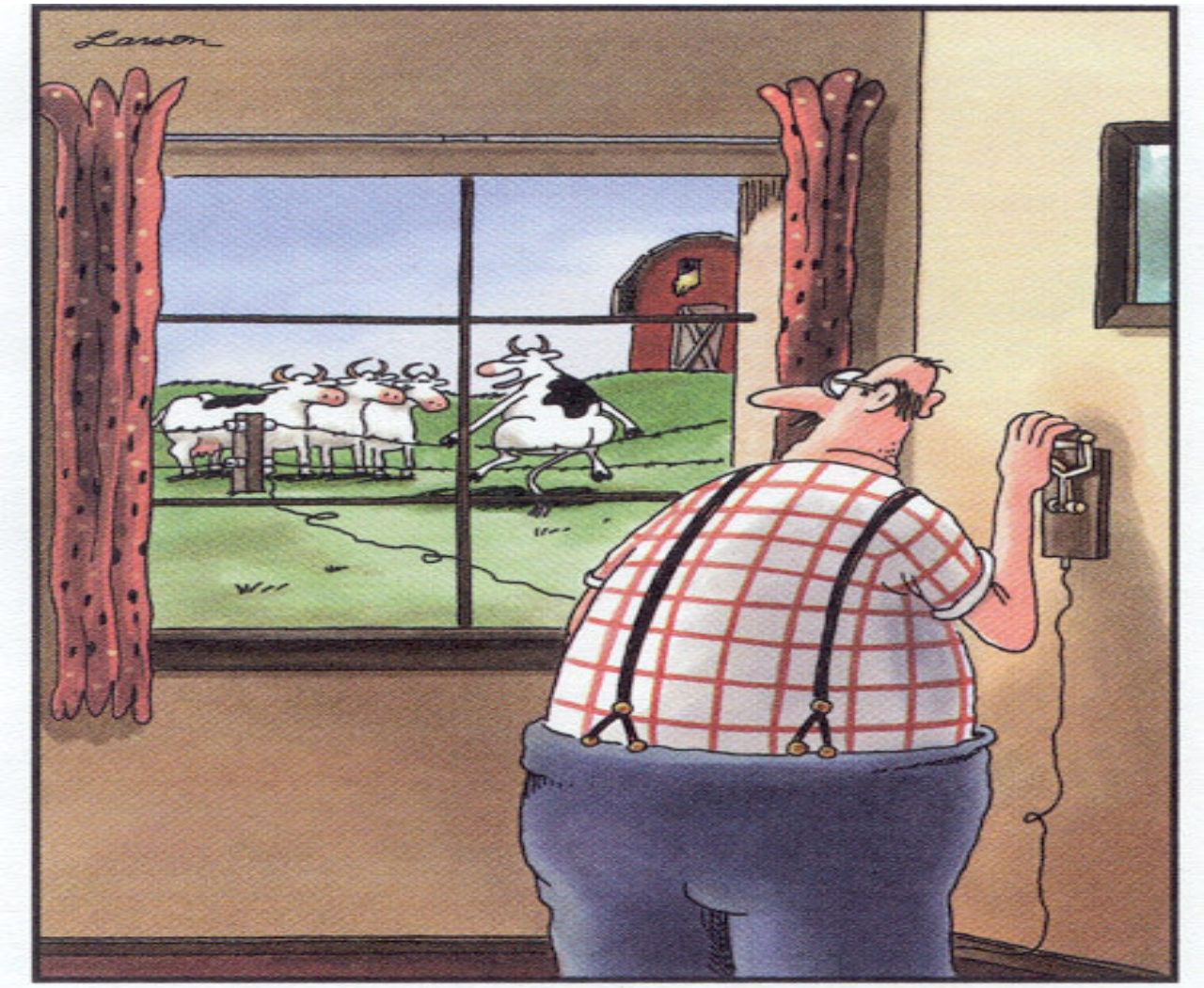
Powering Business Worldwide

Arc flash safety

- On average, only 1 out of every 240 workplace accidents involve electricity (0.4%)
- However, 1 out of every 24 work related deaths involve electricity (4%)

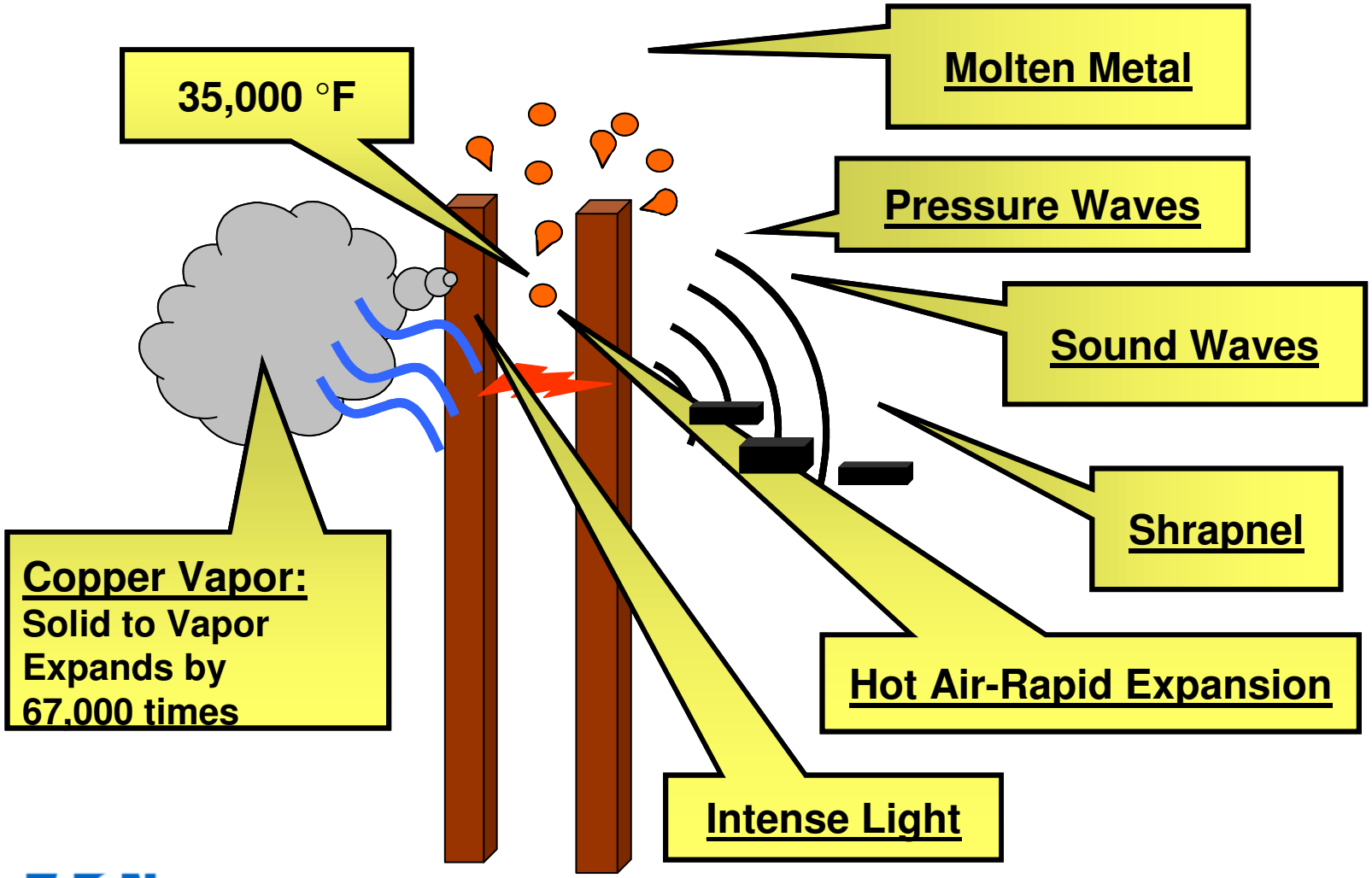
This underlines the need for strong emphasis on Electrical Safety

Arc flash safety



"Look, if it was electric, could I do this?"

Why is an arc a hazard?



Unfortunately – bad things can and do happen

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Potential causes of arc flash events

- Poorly maintained equipment
- Poor operating environments
- Conductive objects left in equipment
- Dropping conductive objects into equipment
- Insulation breakdown (MV typically)
- Animal ingress

Codes and Standards Related to Arc Flash Safety

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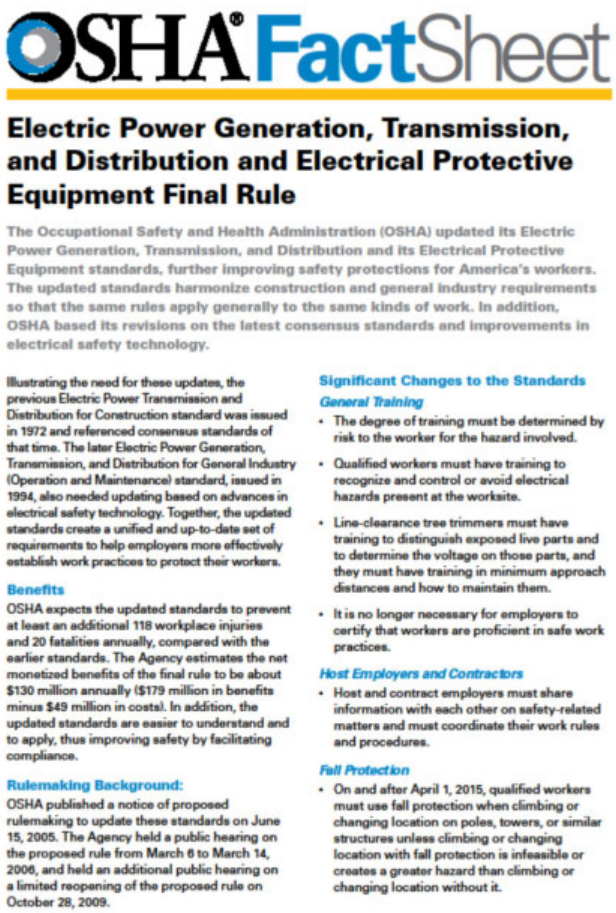
New OSHA electrical safety final rule published

- OSHA does not support the NFPA 70E “table methods” in terms of estimating incident energy
- Additional language recognizes the latest NFPA 70E consensus standards should be the foundation for safety standards.

New OSHA electrical safety final rule published



OSHA FactSheet

Electric Power Generation, Transmission, and Distribution and Electrical Protective Equipment Final Rule

The Occupational Safety and Health Administration (OSHA) updated its Electric Power Generation, Transmission, and Distribution and its Electrical Protective Equipment standards, further improving safety protections for America's workers. The updated standards harmonize construction and general industry requirements so that the same rules apply generally to the same kinds of work. In addition, OSHA based its revisions on the latest consensus standards and improvements in electrical safety technology.

Illustrating the need for these updates, the previous Electric Power Transmission and Distribution for Construction standard was issued in 1972 and referenced consensus standards of that time. The later Electric Power Generation, Transmission, and Distribution for General Industry (Operation and Maintenance) standard, issued in 1994, also needed updating based on advances in electrical safety technology. Together, the updated standards create a unified and up-to-date set of requirements to help employers more effectively establish work practices to protect their workers.

Benefits

OSHA expects the updated standards to prevent at least an additional 118 workplace injuries and 20 fatalities annually, compared with the earlier standards. The Agency estimates the net monetized benefits of the final rule to be about $130 million annually ($179 million in benefits minus $49 million in costs). In addition, the updated standards are easier to understand and to apply, thus improving safety by facilitating compliance.

Rulemaking Background:

OSHA published a notice of proposed rulemaking to update these standards on June 15, 2005. The Agency held a public hearing on the proposed rule from March 6 to March 14, 2006, and held an additional public hearing on a limited reopening of the proposed rule on October 28, 2009.

Significant Changes to the Standards

General Training

- The degree of training must be determined by risk to the worker for the hazard involved.
- Qualified workers must have training to recognize and control or avoid electrical hazards present at the worksite.
- Line-clearance tree trimmers must have training to distinguish exposed live parts and to determine the voltage on those parts, and they must have training in minimum approach distances and how to maintain them.
- It is no longer necessary for employers to certify that workers are proficient in safe work practices.

Host Employers and Contractors

- Host and contract employers must share information with each other on safety-related matters and must coordinate their work rules and procedures.

Fall Protection

- On and after April 1, 2015, qualified workers must use fall protection when climbing or changing location on poles, towers, or similar structures unless climbing or changing location with fall protection is infeasible or creates a greater hazard than climbing or changing location without it.

Key changes

- The employer must assess the workplace to identify workers exposed to flame or electric-arc hazards.
- No later than January 1, 2015, employers must estimate the incident heat energy of any electric-arc hazard to which a worker would be exposed.
- No later than April 1, 2015, employers generally must provide workers exposed to hazards from electric arcs with protective clothing and other protective equipment with an arc rating greater than or equal to the estimated heat energy.

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NFPA 70E – Standard for Electrical Safety In The Workplace – key 2015 changes

- Amended the definition of a “qualified person”
  - One who has demonstrated the skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

NFPA 70E – Standard for Electrical Safety In The Workplace – key 2015 changes

- Changed term to “Arc Flash Risk Assessment” rather than “Arc Flash Hazard Analysis”
  - Separating terms “Risk” and “Hazard”
  - Risk Assessment includes not only the severity, but also the likelihood
- No more “Hazard Risk Categories” – Replaced with “Arc Flash PPE Category”

NFPA 70E – *Standard for Electrical Safety In The Workplace* – key 2015 changes

- *Provides tables for required PPE level – Now based on Equipment type rather than task*

Table 130.7(C)(15)(A)(b) Arc-Flash Hazard PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc-Flash Boundary
Panelboards or other equipment rated 240 V and below Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 455 mm (18 in.)	1	485 mm (19 in.)
Panelboards or other equipment rated >240 V and up to 600 V Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 455 mm (18 in.)	2	900 mm (3 ft)
600-V class motor control centers (MCCs) Parameters: Maximum of 65 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 455 mm (18 in.)	2	1.5 m (5 ft)
600-V class motor control centers (MCCs) Parameters: Maximum of 42 kA short-circuit current available; maximum of 0.33 sec (20 cycles) fault clearing time; working distance 455 mm (18 in.)	4	4.3 m (14 ft)

- ***Separate tables for AC and DC***

NFPA 70E – Standard for Electrical Safety In The Workplace – key 2015 changes

- Removed Hazard Risk (PPE) Category 0
- Added PPE Tables:

Table 130.7(C)(16) Personal Protective Equipment (PPE)

PPE Category	PPE
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2** (see Note 1) Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated face shield (see Note 2) or arc flash suit hood Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy duty leather gloves (see Note 3) Leather footwear (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2** (see Note 1) Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated flash suit hood or arc-rated face shield (see Note 2) and arc-rated balaclava Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy duty leather gloves (see Note 3) Leather footwear

NFPA 70E – Standard for Electrical Safety In The Workplace – key 2015 changes

- Emphasis on proper maintenance per manufacturer's recommendations and installation per NEC and industry standards
- Defines "normal operation" under energized work as performed on equipment that:
  - Is properly installed
  - Is properly maintained
  - Has doors closed and secured
  - Has all covers in place and secured
  - Has no evidence of impending failure

NFPA 70E – Standard for Electrical Safety In The Workplace – key 2015 changes

- Equipment Labeling
  - *"Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling units and that are likely to require examination, adjustment, servicing, or maintenance while energized shall be field-marked"*

- Label must include: (red text in 2012 version)
  1. Nominal system voltage
  2. Arc Flash boundary
  3. One of the following:
     1) Either the arc flash PPE category from the tables OR available incident energy and corresponding working distance, but not both on the same piece of equipment.
     2) Minimum arc rating of clothing
     3) Site specific level of PPE

NFPA 70E – Standard for Electrical Safety In The Workplace

- Requires safety “re-training” at intervals of not more than 3 years (not new – added in 2012)
- The arc flash risk assessment must be updated after any major renovation or at a intervals not to exceed 5 years.

  (not new – added in 2009)

Arc flash hazard 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)

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

Presentation Outline

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

Label Equipment

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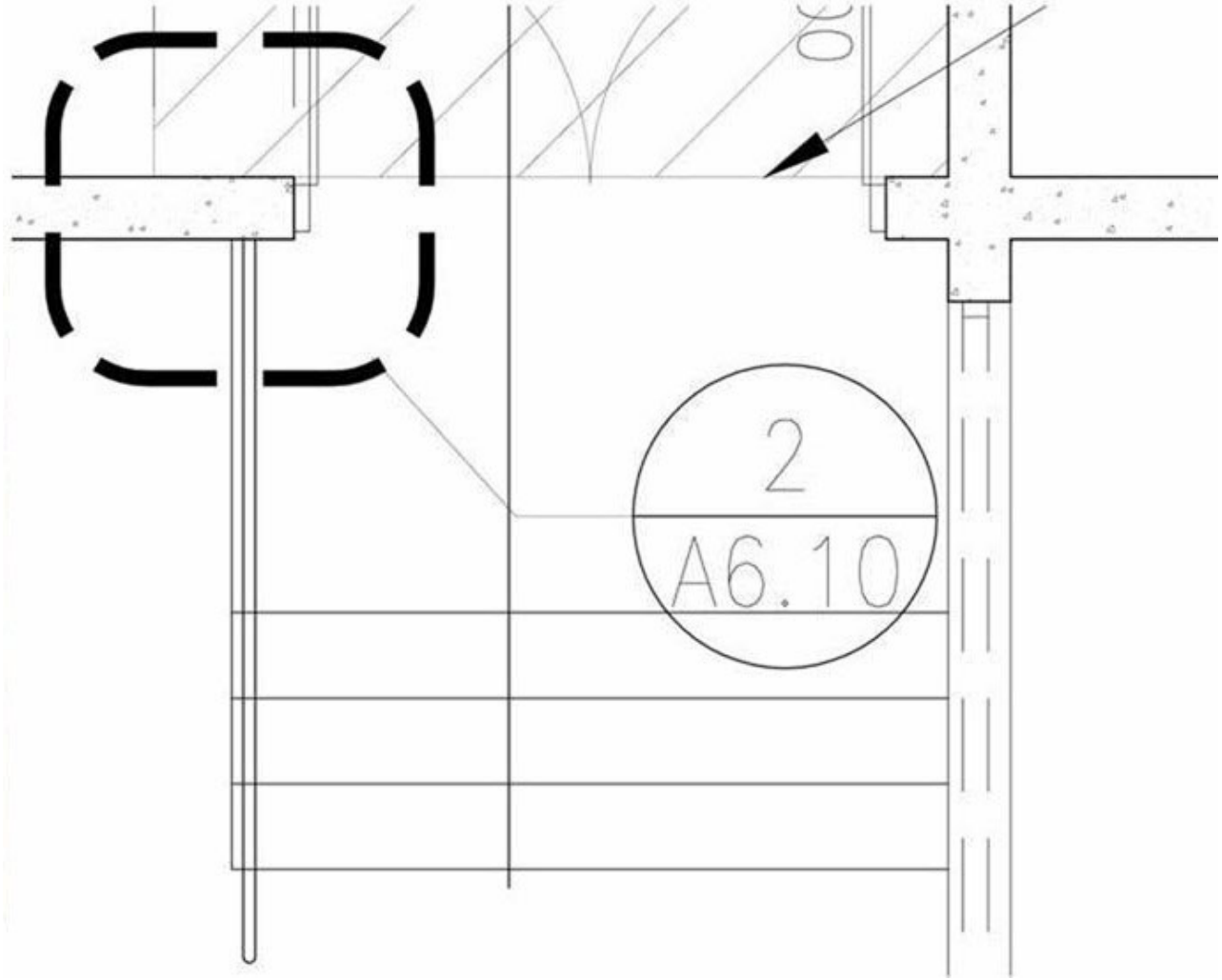
Proper labeling is imperative to make sure you get your message across…..

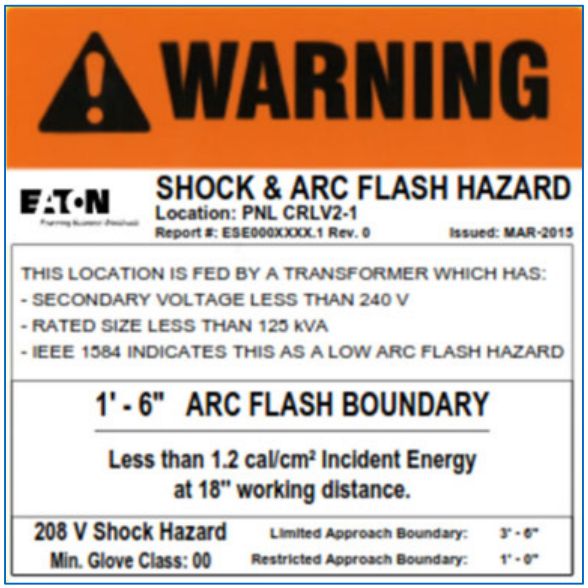
Get it?

It is very important that you understand how to interpret labeling



It is very important that you understand how to interpret labeling

Sample Arc Flash Labels



- Information is not intuitive!
- Without proper training, crucial safety information on the labels will be ignored

Train Personnel On Proper Safety Practices

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The Top 6 Safest Practices…

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Number 6…

Taking safety to new heights…

Number 5…

Yankee ingenuity…

Number 4…

From the Stevie Wonder School of fork lift operation

Number 3…

PPE = Pink Personal Equipment

Number 2…

It's only low-voltage…

Number 1…

The Darwin/MacGyver Award goes to these guys

Train personnel to use “good” safety practices

Bad – Exposed Back of Neck, Head and Hair

Better– All of Body Protected

Best

Train personnel to use “good” safety practices

Potentially exposed ankles

Reduce Available Fault Current (Reduce Incident Energy)

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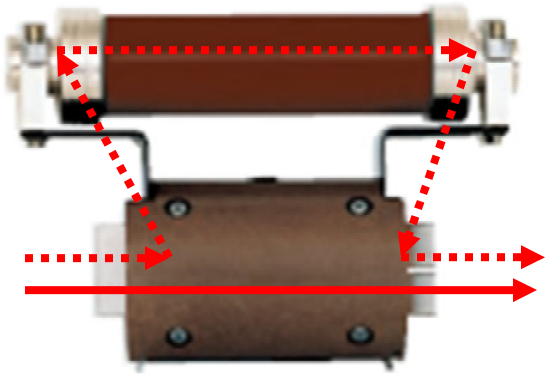
Reduce the available fault current through added impedance

- Use small kVA isolation transformers / current limiting reactors
- NOTE: Lowering short circuit current does not always lower incident energy
- There is no single answer
- Must conduct an arc flash study
  - Must have accurate information
  - Estimates/assumptions can dramatically change the results

Reduce the available fault current through current limiting

- Active devices that force current through a current limiting element when fault current exceeds a predetermined value

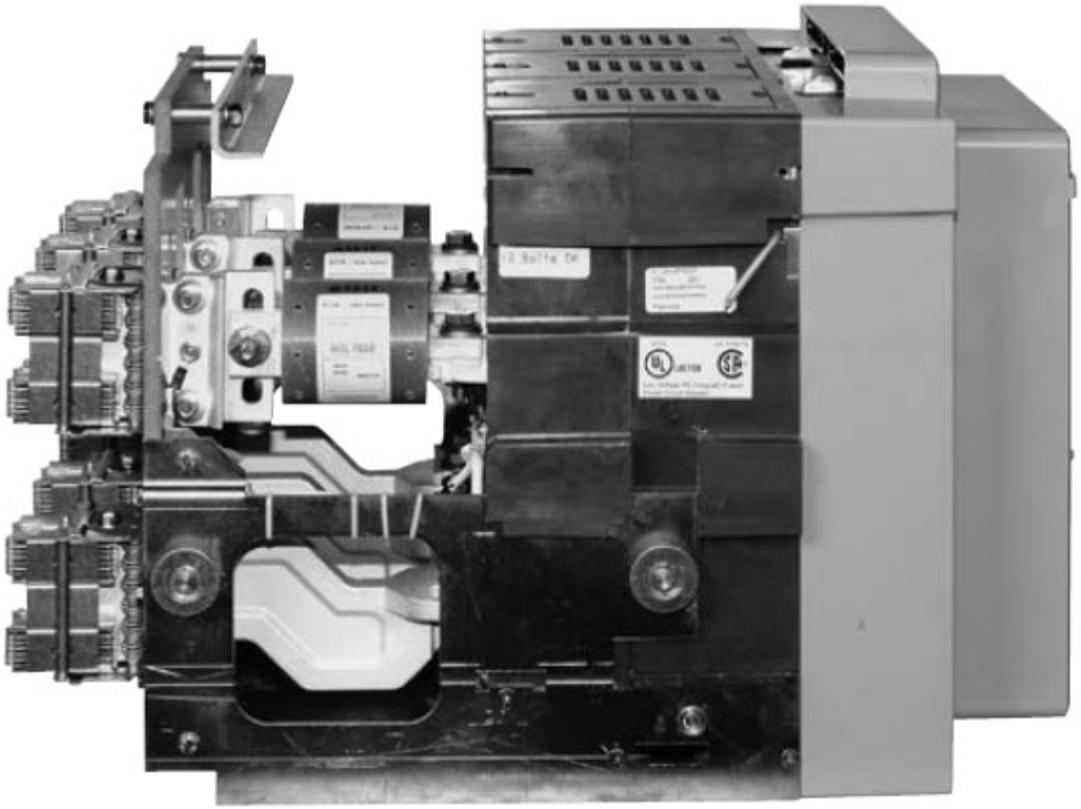


Normal current path

High fault current path

Combination circuit breakers

- Power circuit breakers with integral current limiters provide the best of both worlds.
  - Current limitation under high fault conditions
  - Fast opening for lower level faults
  - Self-powered overload protection
  - Trip units with communications, metering, ZSI, GF protection, etc
  - Remote control capability



Redirect Fault Energy –
ANSI / IEEE Arc Resistant Switchgear

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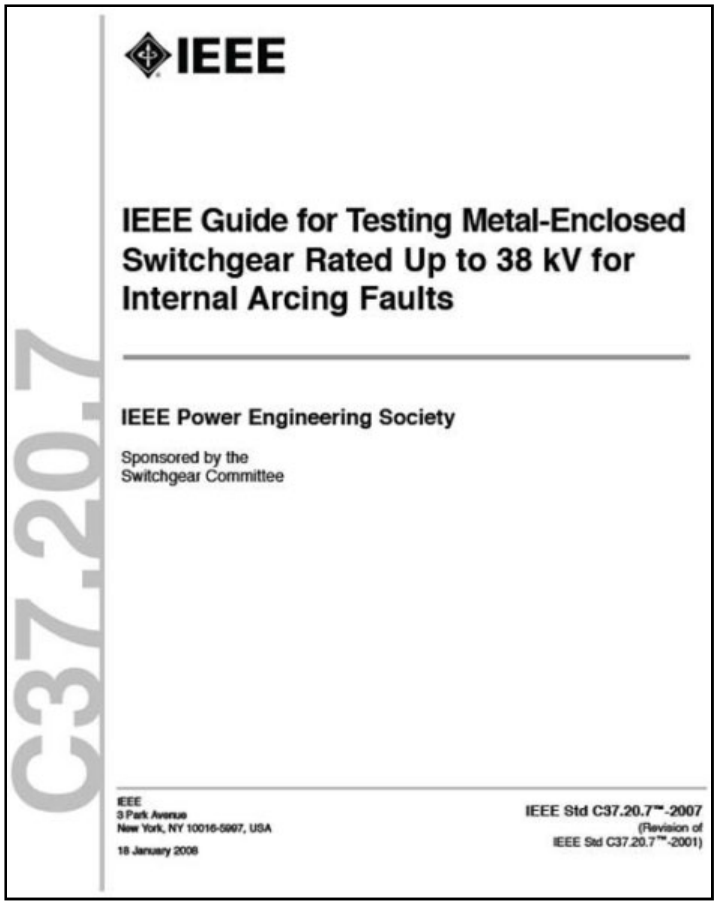
Arc flash protection guidelines and standards update

- ANSI / IEEE C37.20.7
  - IEEE Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults
  - 2007 Latest Edition
- Gives testing guidelines for confirming arc resistant capability of metal-enclosed switchgear
  - Manufacturer's are given significant latitude in how their assemblies can be tested
- New guide in development will address LV MCC, MV MCC, switchboards, non seg bus and possibly gas insulated switchgear



Not all Arc Resistant assemblies are created equally. It is important to understand the specific ratings and capabilities. Do not just rely on statements such as "Tested per ANSI/IEEE C37.20.7".

Typical arc resistant switchgear test configuration

Test is successful if:

- No indicators burn
- Doors do not open
- No projectiles >60 g come from equipment lower than 2 meters
- No holes are burned in the enclosure at a height lower than 2 meters
- All grounds remain intact

Arc Resistant Switchgear – Arc Test Duration

- IEEE C37.20.7, section 4.3 gives a **"preferred" arcing duration rating of 0.5s**, but allows a rating as low as 0.1s depending on the speed of the main protective device used in the testing.
  - Duration Rated vs. Device Limited
- C37.20.7 allows the use of protective devices, relays, schemes, ZSI, and other fast acting mechanisms to limit the arcing energy by shortening the duration of the event.
  - The equipment nameplate is required to indicate if the arc rating is based upon active devices/systems.

Important to understand what "active" elements are required to function for the operator to have the expected level of safety protection.

Arc resistant switchgear – arc initiation location

- IEEE C37.20.7, requires that the arc be initiated in the “most likely location” of an arcing event.
- In compartmentalized switchgear assemblies, where is the most likely location of an arcing fault?
  - Cable compartment?
  - Main Bus Compartment?
  - Breaker Compartment?
- Location of the arc has a TREMENDOUS affect on the enclosure’s ability to contain the arc energy and/or channel it away from an operator.
- The location of the arc initiation point impacts:
  - Steel thickness
  - Door latch requirements
  - Pressure relief systems and locations
  - Arc blast exhaust path
- Component location and configuration
  - Changes in component layout inside the assembly can affect the ability of the enclosure to contain the arc blast.

Arc resistant switchgear – application & installation considerations

- ✓ What is the kA & time rating required for the equipment?
- ✓ Is direct venting with arc exhaust duct possible?
- ✓ If arc exhaust duct is required, how many? Has a safe exhaust location been determined? Has the duct layout been established? Is any duct required to be outdoor with a NEMA 3R rating?
- ✓ In what environment will the switchgear be placed? (ie. switchgear room, IPA, C1D2 area, basement?) Is a firewall required at exhaust penetration?
- ✓ Is close coupling to other equipment (ie. switches, transformers, motor starters) required? If so, are common plenums available? Multiple ducts?

Modification of the enclosure is not allowed, as it may void arc resistant rating!

Arc resistant switchgear – protection types

IEEE C37.20.7 (USA)

- Type 1 - Arc resistant at front only
- Type 2 - Arc resistant around the perimeter of the switchgear line-up

Appendix A

- Suffix B - Arc resistant to Type 1 or 2 with control door open.
- Suffix C - Arc resistant to Type 1or 2 plus between adjacent compartments.
- Suffix D - specifies Type 1 and applicable accessible sides

EEMAC G14-1 (Canada)

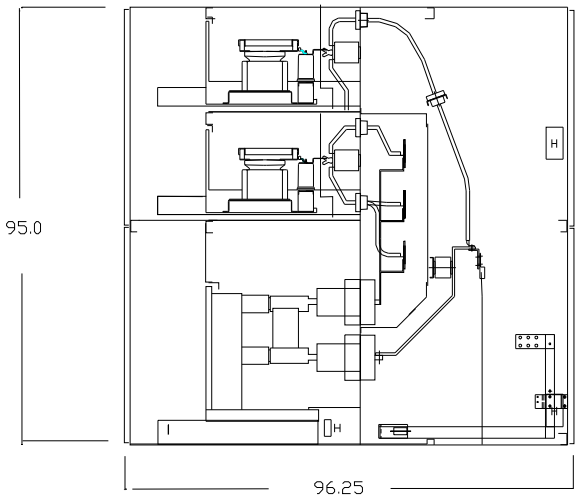
- Type A - Arc resistant at front only
- Type B - Arc resistant around the perimeter of the switchgear line-up
- Type C - Arc resistant to Type B plus between all adjacent compartments.

IEC 62271-200 (Rest of World)

- Type A - Arc resistant for restricted areas. IE. Authorized personnel ONLY
- Type B - Arc resistant for unrestricted areas. IE. General public access.
- Type C - Pole Mounted Equipment
- (accessibility types: F-front side, L-lateral side & R- rear side)

Arc resistant switchgear – key take away

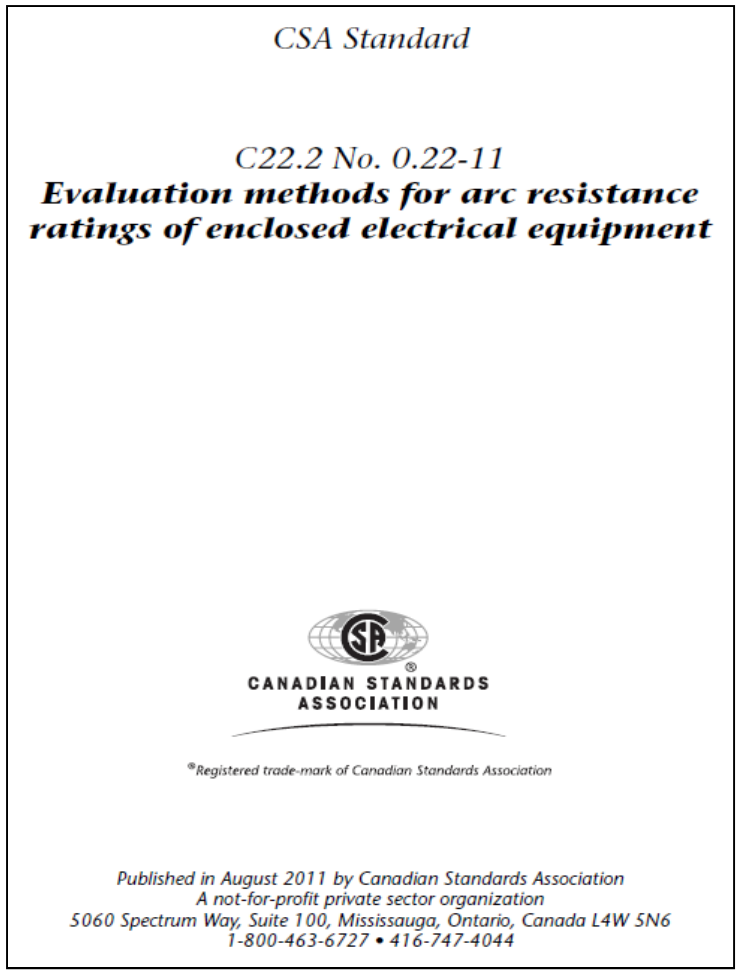
- The most rigorous arc resistant switchgear testing plan includes initiating arcs in <u>all compartments</u> (breaker, bus, & cable) for a full 0.5s, to guarantee the safest arc resistant switchgear.



Some manufacturer's do not publish detailed arcing duration or arc initiation information on their products which claim to be Arc Resistant "per ANSI C37.20.7"

Canadian arc resistant protection guideline

- CSA C22.2 No. 0.22-11 published in August 2011
- Draws on a number of standards addressing arc resistance of enclosed electrical equipment
- Scope of coverage is indoor and outdoor equipment up rated up to 46 kVac that uses air as the primary insulating medium
- Testing and evaluation criteria based primarily on IEEE C37.20.7
  - Much of the text reads the same
  - Assessment criteria is identical


CSA Standard

C22.2 No. 0.22-11

Evaluation methods for arc resistance ratings of enclosed electrical equipment

CANADIAN STANDARDS ASSOCIATION

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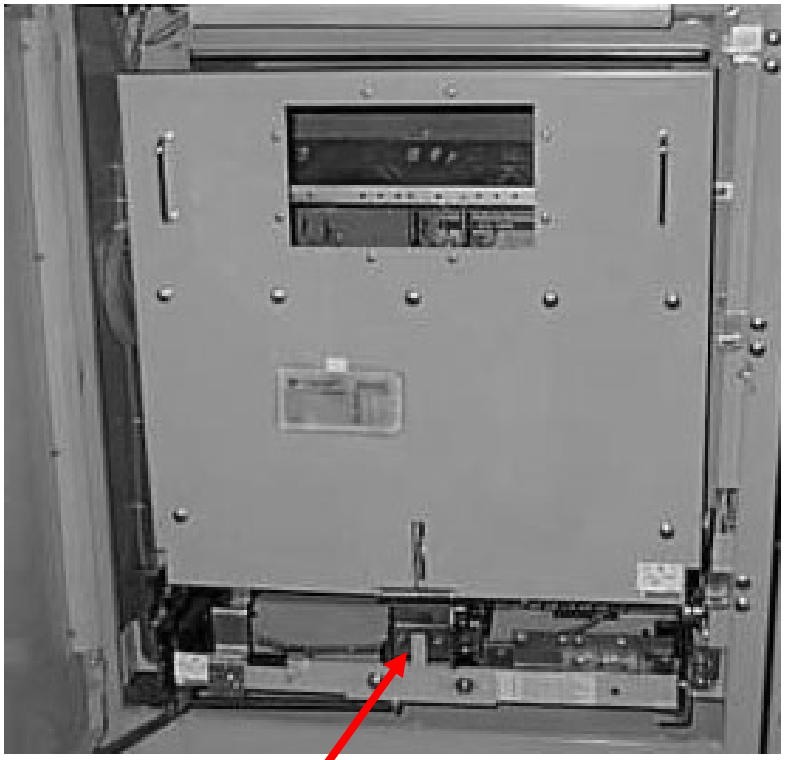
Published in August 2011 by Canadian Standards Association
A not-for-profit private sector organization
5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N6
1-800-463-6727 • 416-747-4044

Arc resistant metal-clad switchgear features

- Heavier gauge reinforced doors and covers
- Closed Door Breaker Operation
  - Breaker Racking
  - Manual Open
  - Viewing of Breaker Status & Position

Arc resistant metal-clad switchgear

Draw-Out Auxiliary Drawers



All auxiliary drawers are equipped with levering mechanism

Auxiliary Racking Mechanism is accessible through the door

Arc resistant switchgear – Type 2B
Relays and controls can be mounted on the breaker door

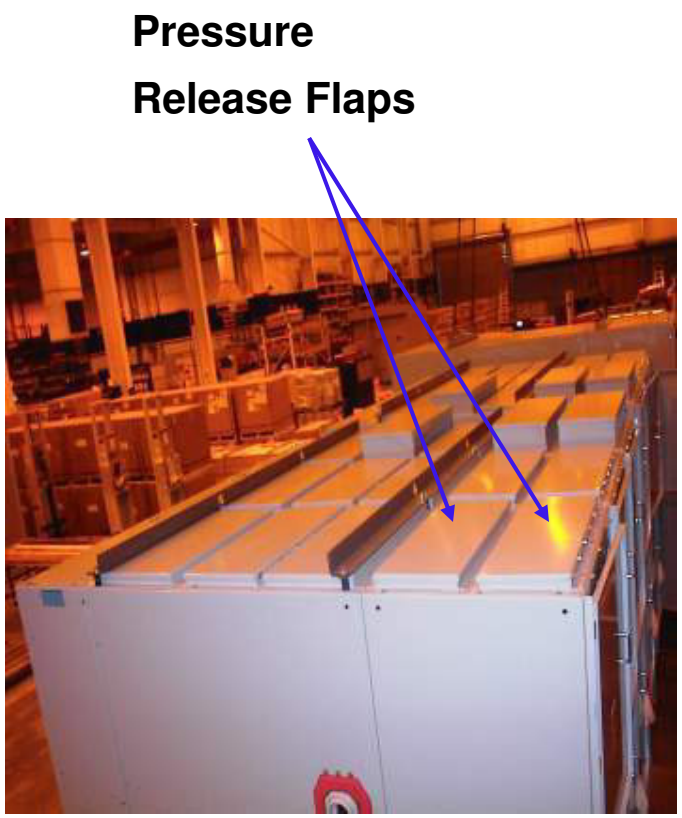
Sealed relay compartment on the front of the breaker door is hinged for easy access.

Breaker access door is interlocked such that door can not be opened until breaker is in disconnected position

Typical arc resistant switchgear assembly

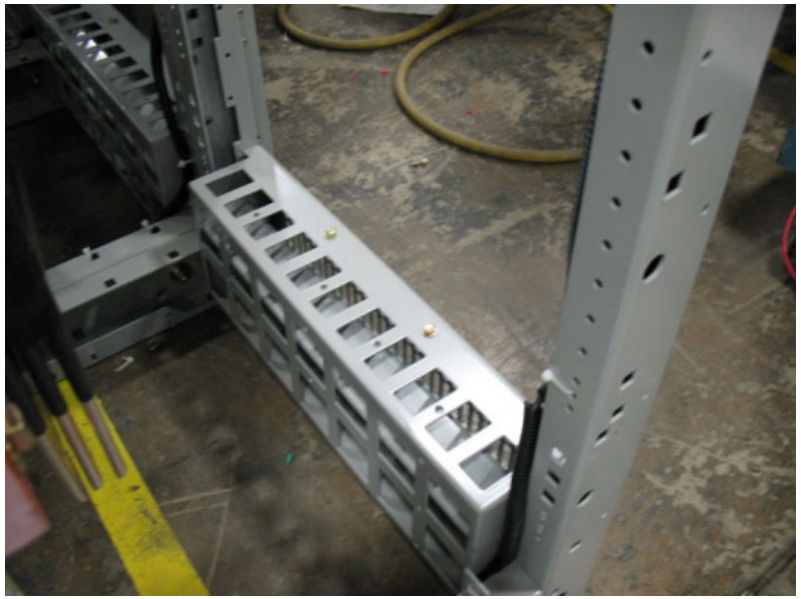
Rugged Construction

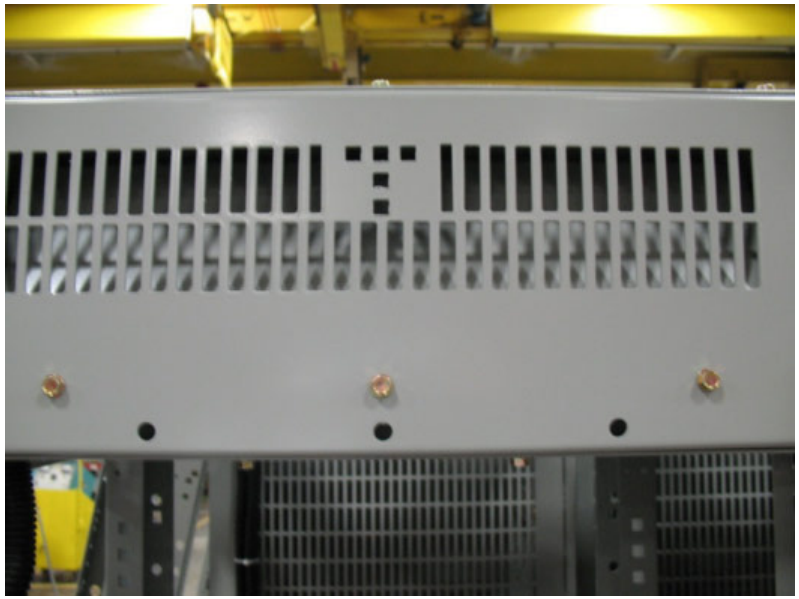
- Formed steel compartment design provides sealed joints under fault conditions.
- Roof mounted pressure release flaps allow for the release of arc exhaust
- Arc pressure exits through top of each individual vertical section



Dynamic flap system

- Ventilation openings must seal under arc condition, but must remains open during normal operation for proper ventilation of equipment. Dynamic Flaps utilize gravity to hold open, and will quickly close under the pressure of an arcing event.

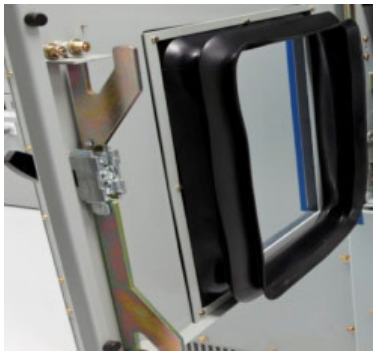




Arc resistant LV switchgear – design features

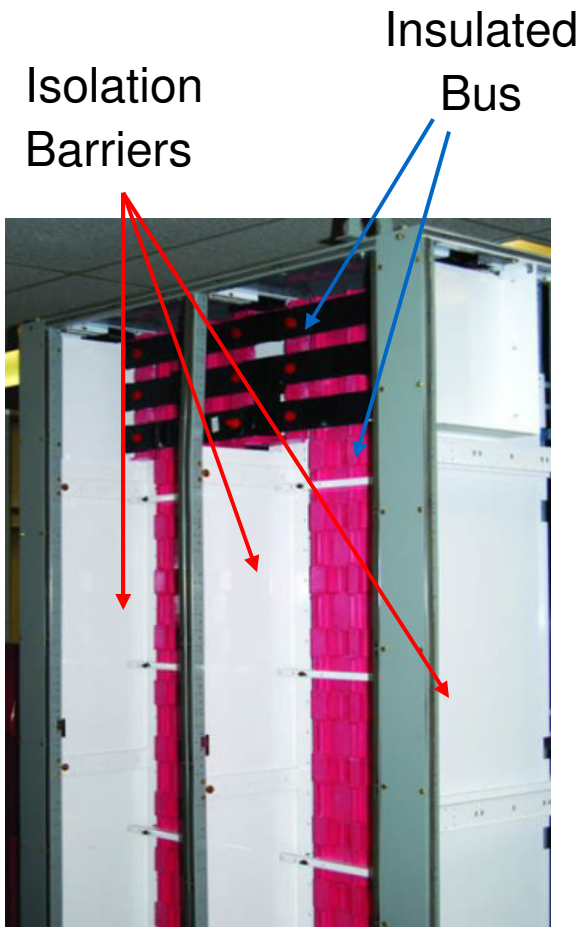
Key Features:

- ✓ Through-the-door breaker design
- ✓ Arc resistance on all 4 sides (Type 2)
- ✓ Secondary terminations and control compartment access (Type 2B)
- ✓ Stronger breaker door & latch mechanism
- ✓ 4-high breaker design



LV MCC arc resistant features

- Device limited (vs. duration limited) ratings are common for this class of equipment
- Arc Prevention Features
  - Insulated horizontal bus and vertical bus
  - Automatic bucket shutters
  - Isolation barriers installed between each structure
    - Serves to help isolate and contain the arc flash event within a single structure



Shield the operator with closed doors/panels

- Infrared (IR) Scanning Windows
- On arc resistant equipment, make sure brand was arc tested on the specific equipment and in specific mounting location.

Faster Clearing Time

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2014 NEC – key change to reduce 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"

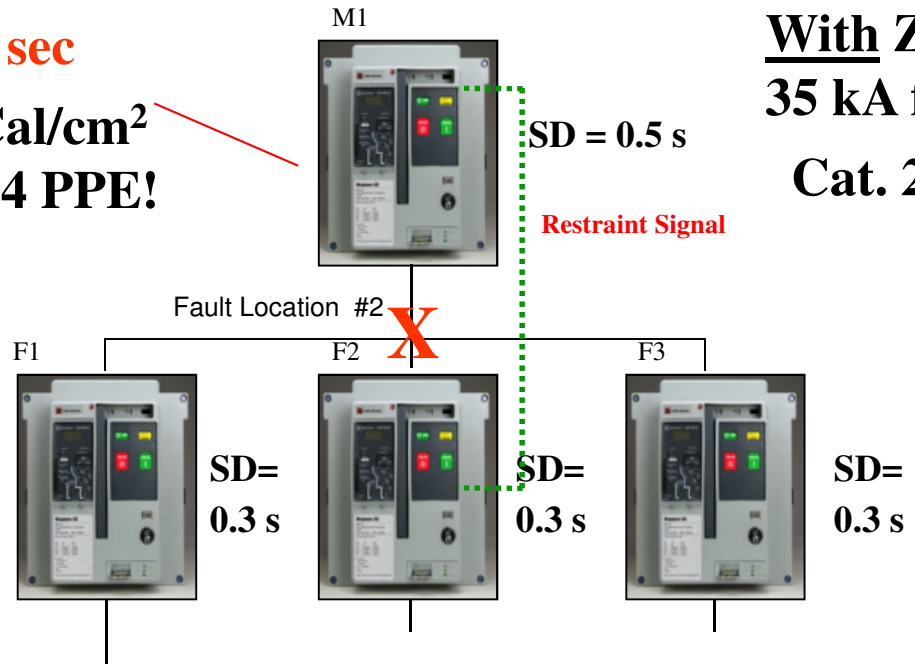
Doesn't quantify any required level of reduction.

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

Zone Selective Interlocking example

Without ZSI = 0.5 sec

35 kA fault, 43.7 Cal/cm²
Greater than Cat. 4 PPE!



With ZSI = 0.08 sec

35 kA fault, 7.0 Cal/cm²

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.

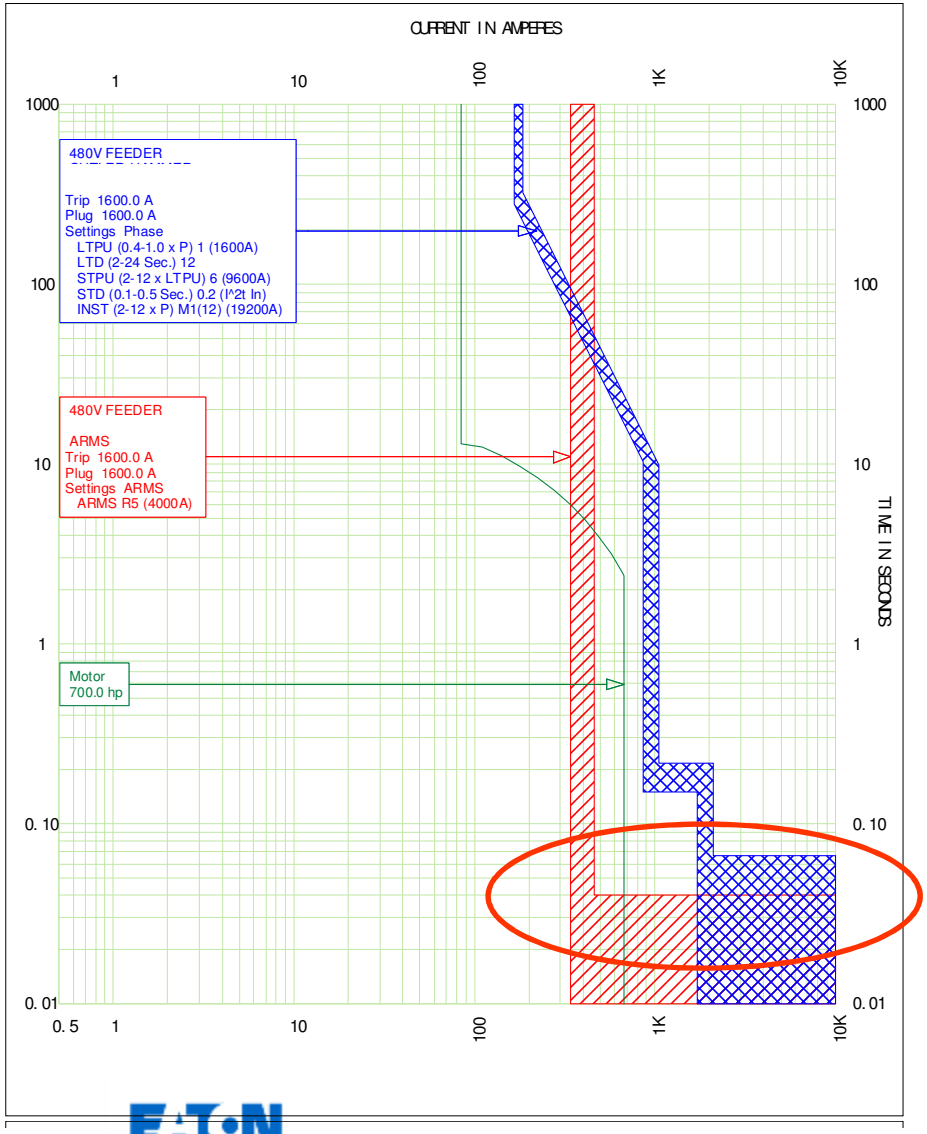
Arc Flash Reduction Maintenance System (ARMS)

Status indicator

Local on/off switch

Current threshold setting to avoid pick-up for high load levels and inrush

Arcflash Reduction Maintenance System (ARMS)



- When activated, total breaker clearing time is reduced to 40 msec!
- One manufacturer's ARMS protection is "faster than instantaneous"
  - Bypasses all microprocessor delays
- 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.

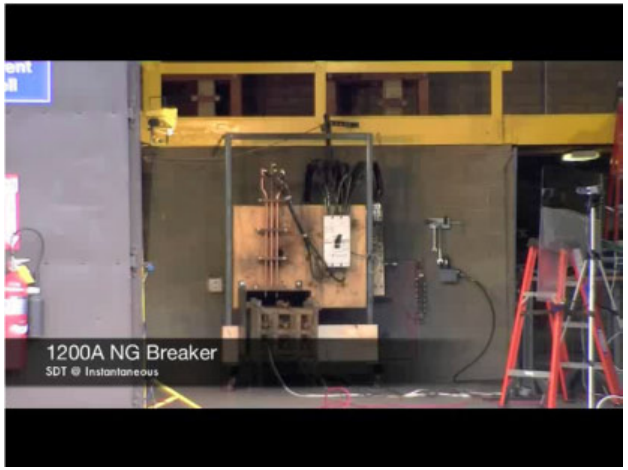
ARMS – features

- Independent from standard overcurrent settings (doesn't require changing the programmed settings)
- Trip times equal to or shorter than instantaneous tripping
- Adjustable to allow maximum reduction without nuisance tripping
- Can be activated:
  1. Locally
  2. Remote selector switch (or dry contact)
  3. Over communications network
- Local status indication (required by code) and at downstream protected equipment
- Must be able to be integrated into normal lockout – tag-out procedures

Actual arc flash incident protected by ARMS

ARMS capability of 1200 A over current protective devices (OCPDs) (9kA @ 480V)

1200 A Fuse



Breaker w/ Instantaneous

Breaker w/ **Maintenance Mode**

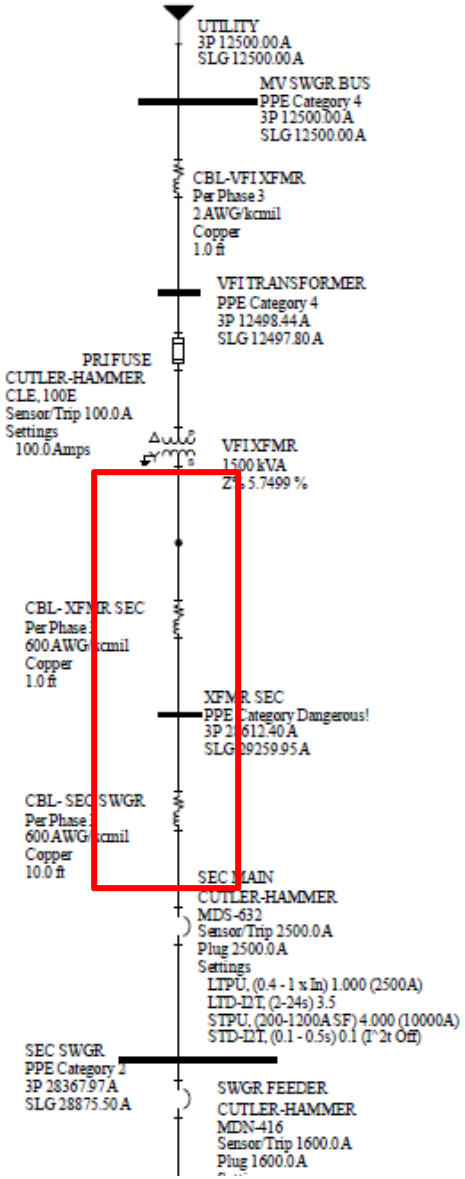
(Click videos to view)

OCPD 1200 A comparison table

(9 kA @ 480 V)

Device	Fuse L-Class	N-frame w/ Instantaneous	N-frame w/ Maint. Mode
Peak Fault Current (kA)	15.7	14.8	14.5
Time to Clear (ms)	771.0	45.9	18.2
[improvement vs. Fuse]	----	94%	98%
[improvement vs. Instantaneous]	----	----	60%
Arcflash Energy (Cal/cm^2)	17.89	1.63	0.41
[improvement vs. Fuse]	----	91%	98%
[improvement vs. Instantaneous]	----	----	75%
Hazard Risk Category (NFPA 70E **2012**)	3	1	0
[Incident Energy Range]	8.0 – 25.0 Cal/cm^2	1.2 – 4.0 Cal/cm^2	0.0 – 1.2 Cal/cm^2

Substation protection – fused transformer

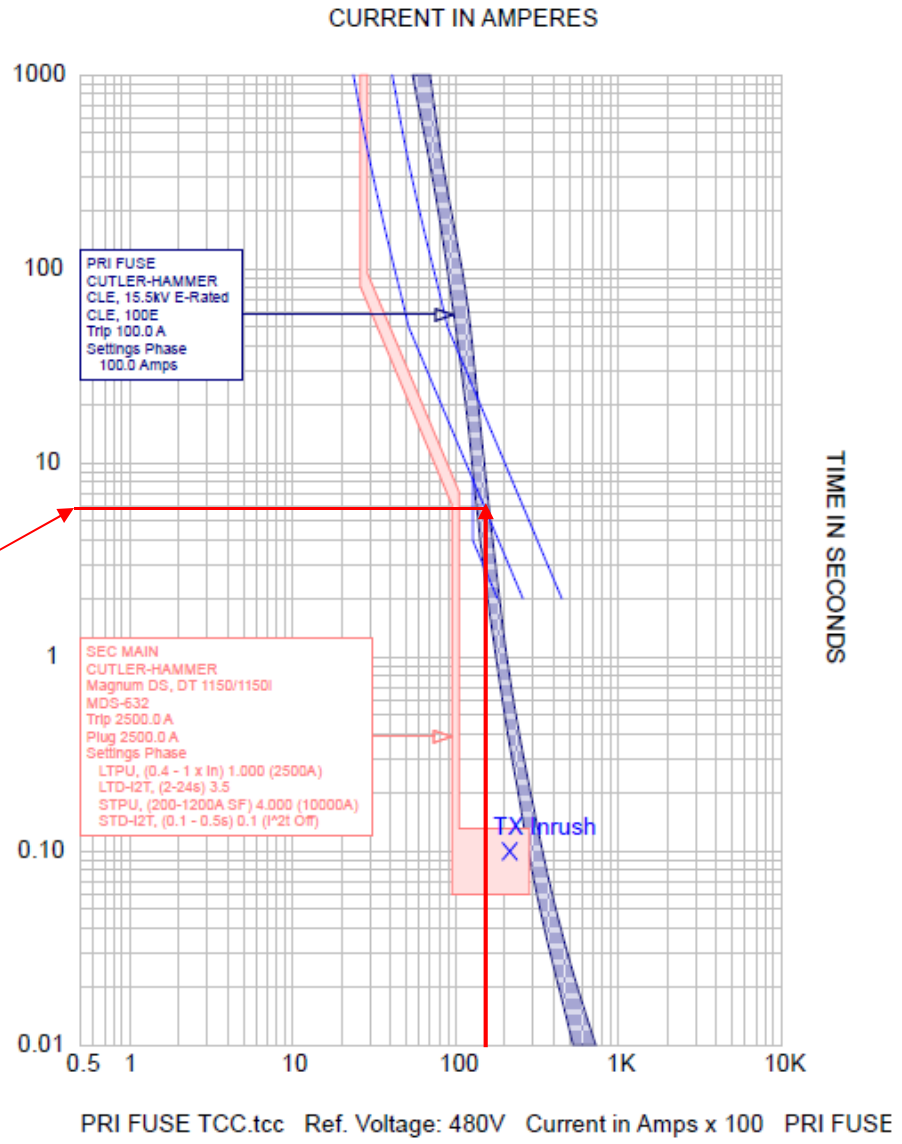


- Secondary of substation transformers are typically high arc flash risk zones (with or without a secondary main)
- Trip times are long because arc faults have to reflect through the transformer
- Primary fuses react very slowly to secondary arcing and ground faults

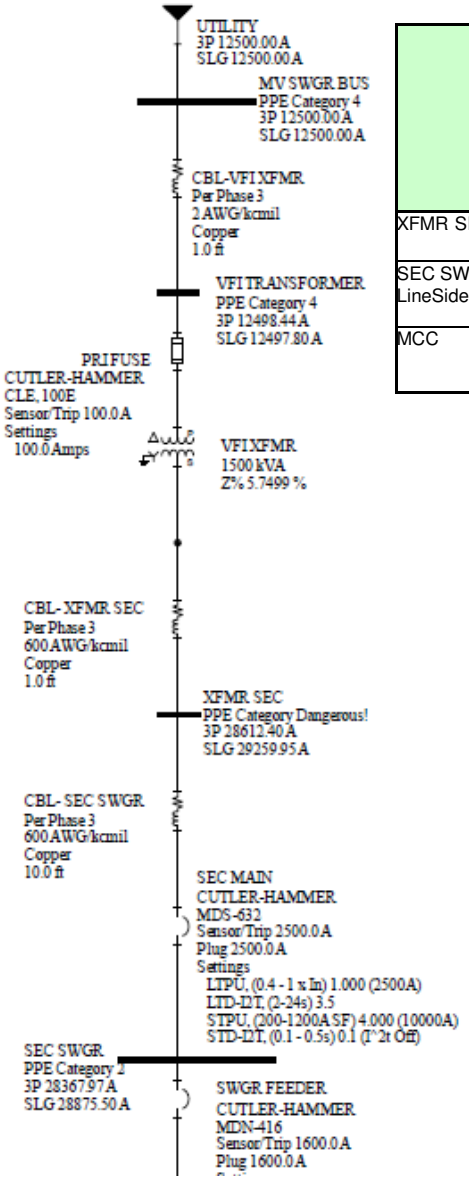
Substation protection - fused transformer

- 1500 kVA xfmr, Z = 5.75%
- Bolted fault current = 28.84 kA
- Arcing fault current = 16.20 kA

Arcing current reflected through transformer would take **in excess of 6 seconds to clear primary fuse!**



Substation protection - fused transformer

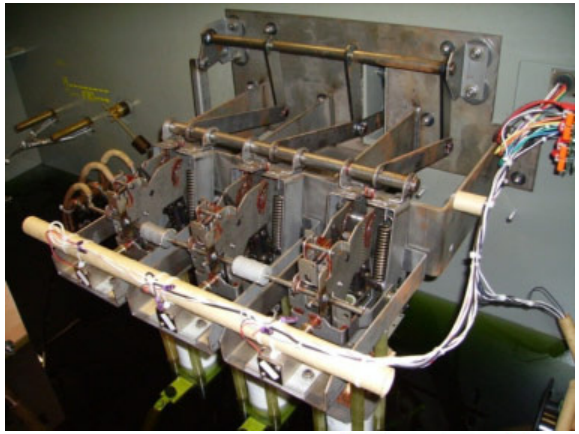


Bus Name	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time/Tol (sec.)	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)	PPE Level / Notes (*N)
XFMR SEC	PRI FUSE	0.48	28.84	28.84	16.20	2	0.000	**286**	18	**112**	**Dangerous!**
SEC SWGR (SEC MAIN LineSide)	PRI FUSE	0.48	28.59	28.59	16.09	2	0.000	**285**	18	**111**	**Dangerous!**
MCC	SWGR FEEDER	0.48	25.30	25.30	14.49	0.065	0.000	**33**	18	**3.2**	**Level 1**

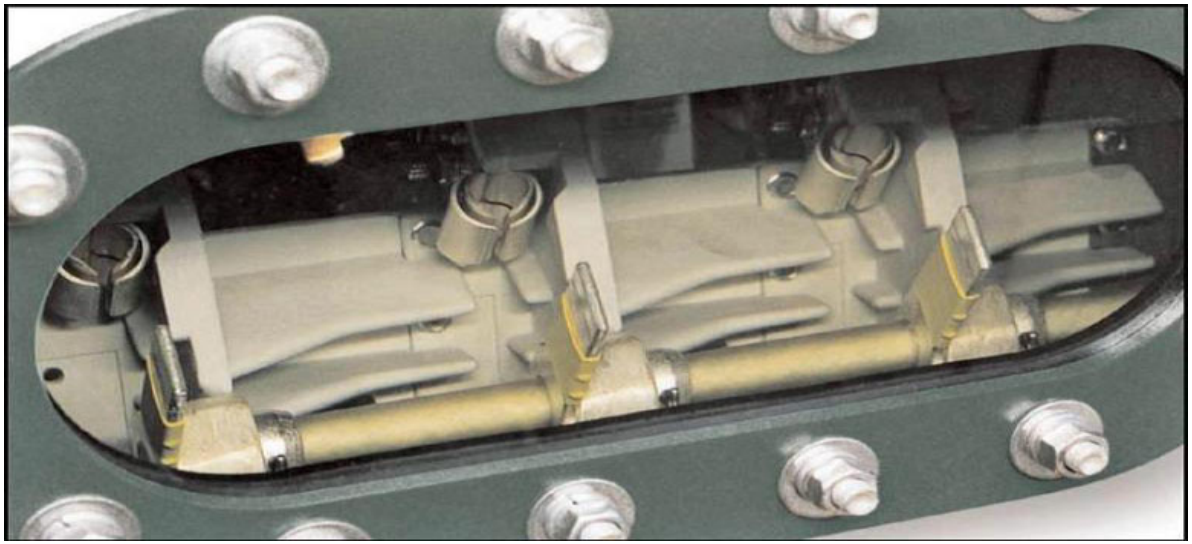
- Anywhere from the xfmr secondary to the line side of the secondary main breaker is arc flash PPE category **DANGEROUS**
- If line side of secondary main breaker is not isolated with barriers to prevent propagation to load side, this level applies to the entire secondary switchgear.

Transformer with integral vacuum interrupters (VIs) on primary

- Under oil vacuum interrupter integral to transformer tank
- 750-10,000 kVA
- Primary: Thru 34500GY/19920 V 150 kV BIL
- 600 A Cont.
- 16,000 A rms interrupting
- Self-powered relay for primary protection
- Saves footprint and $$$ by eliminating separate primary switch or breaker

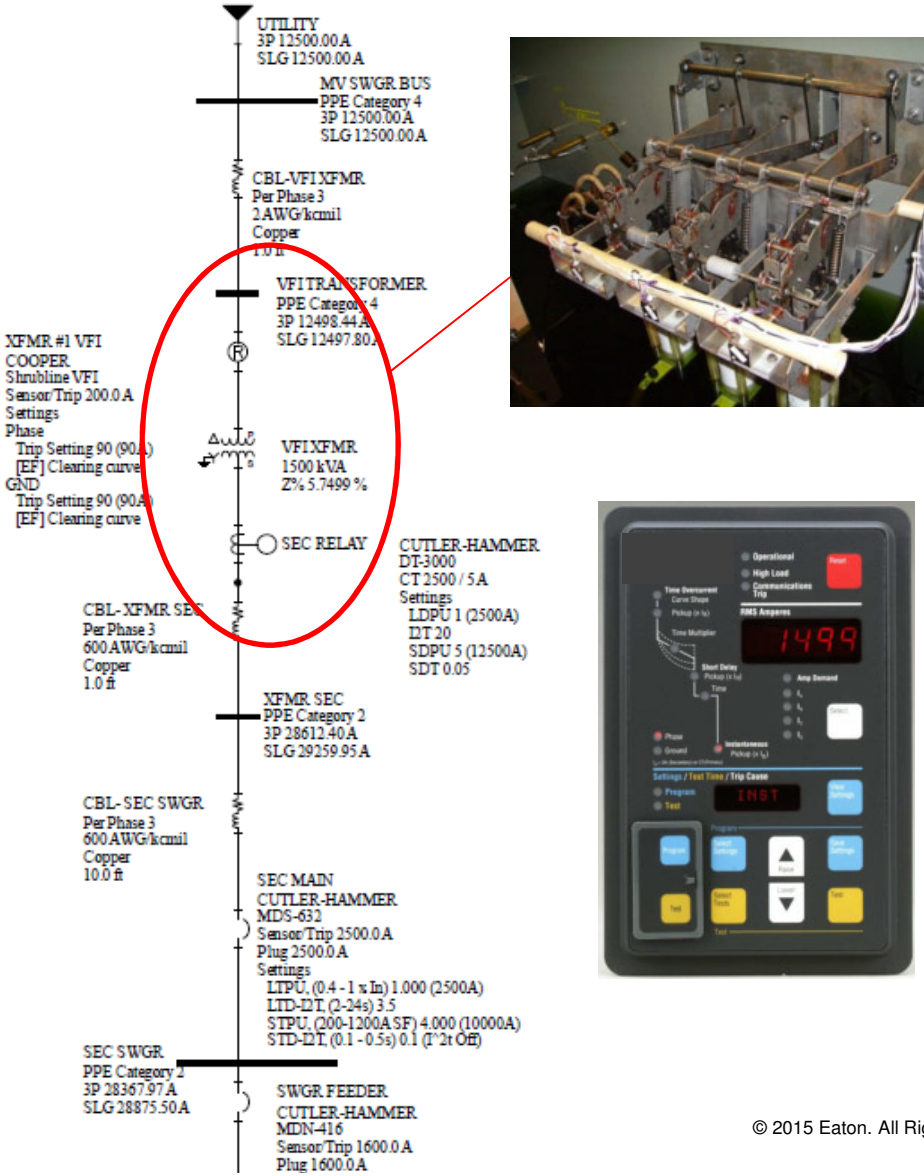


VIs with series visible break



- Optional Visible break available to still allow visible inspection of blade position
- Large, easily viewed knife blades through window
- Closed, open or grounded contact position
- Placed in series with VI mechanism
- Mechanically interlocked to ensure load-break and load-make operations occur in the vacuum interrupters

Substation protection – transformer with integral vacuum interrupters (VIs)



- Replace transformer fuse protection with integral VIs
- Self-powered, adjustable primary protection
- CT's on secondary bushings or spades
- Simple 50/51, 50G/51G overcurrent relay protection on secondary cts
- Ability to trip primary VIs from secondary relay

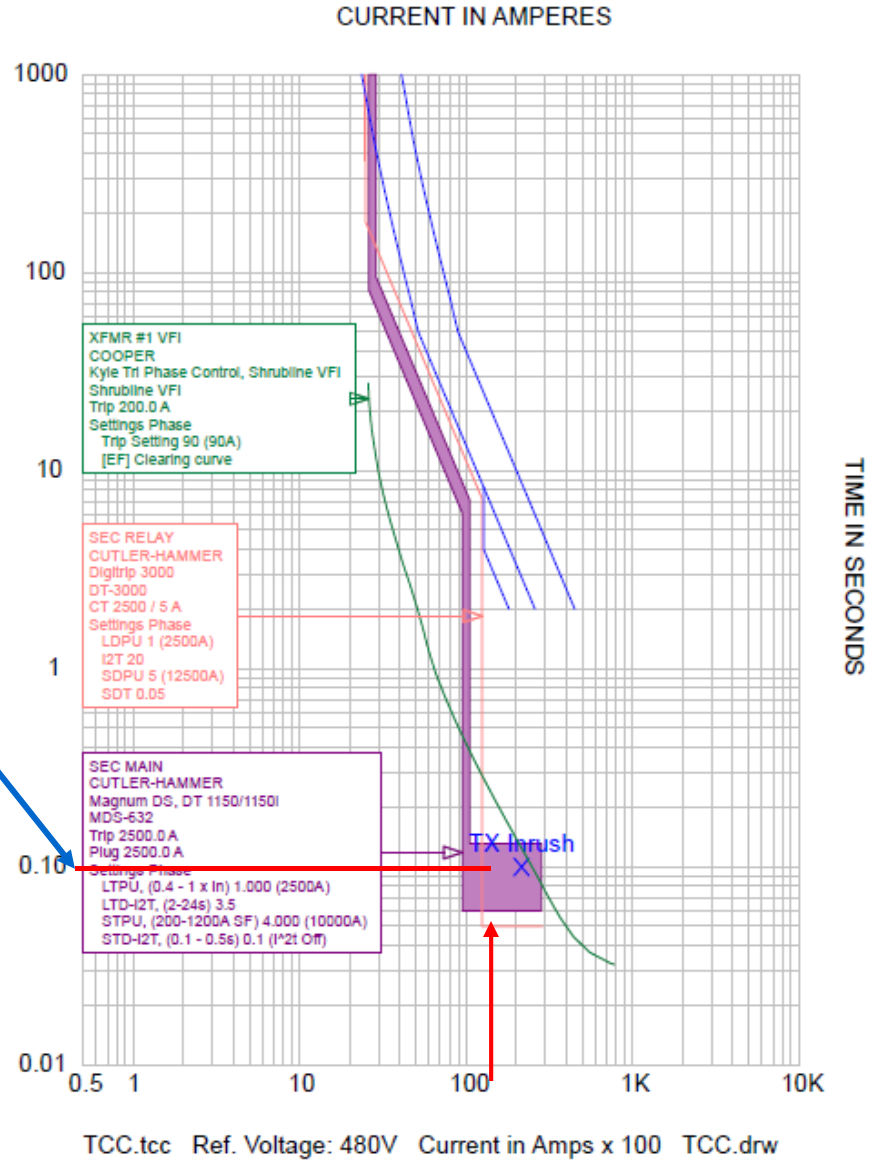
Substation protection – transformer with integral vacuum interrupters (VIs)

- 1500 kVA xfmr, Z = 5.75%
- Bolted fault current = 28.84 kA
- Arcing fault current = 16.20 kA

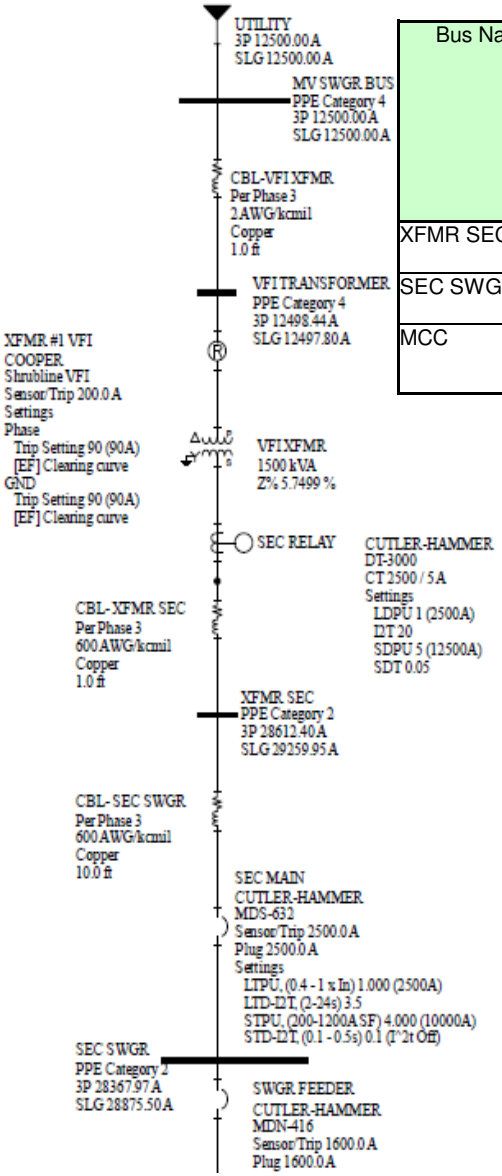
Total clearing time of only 0.100 sec – 0.05 sec for relay operation + 0.05 sec for VI operation (100 msec)!

Completely adjustable protection to allow customization of arc flash reduction versus selective coordination.

- Shown with INST off and delay of 0.05 sec



Substation protection – transformer with integral vacuum interrupters (VIs)



Bus Name	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time/Tol (sec.)	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)	PPE Level / Notes (*N)
XFMR SEC	SEC RELAY	0.48	28.84	28.84	16.20	0.05	0.050	46	18	**5.6**	**Level 2**
SEC SWGR	SEC RELAY	0.48	28.59	28.59	16.09	0.05	0.050	46	18	**5.5**	**Level 2**
MCC	SWGR FEEDER	0.48	25.30	25.30	14.49	0.065	0.000	33	18	**3.2**	**Level 1**

- Anywhere from xfmr secondary to the load side of the secondary main breaker incident energy is reduced to 5.6 cal/cm2 (Category 2)
- Protection applies to entire secondary switchgear
- Increasing secondary relay / main breaker Short Time Delay to 0.3 seconds for better selective coordination only increases incident energy to 11.5 cal/cm2 (Category 3)

Substation protection – transformer with integral vacuum interrupters (VIs)

Liquid Xfmr Advantages:

- Better Efficiency / Less Losses
- Greater Overload Capacity
- Deadfront Construction
- Extended Life
- Integral Primary Protection
- Less Floor Space Required

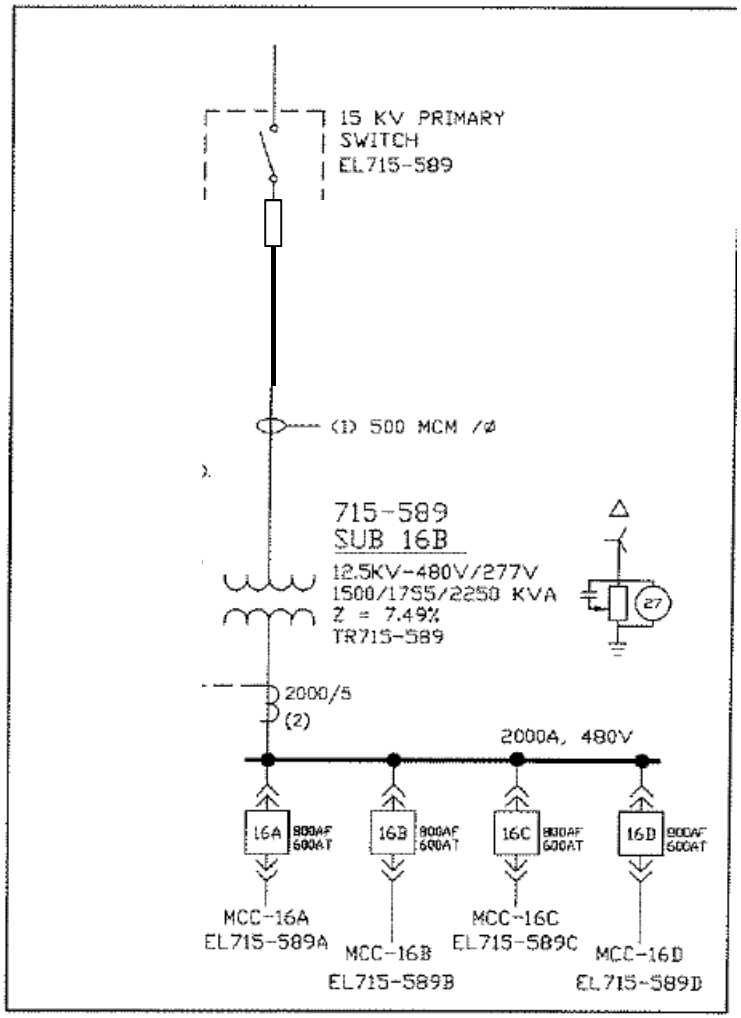
Substation protection – with various vacuum interrupting devices

- Any vacuum switching option on the primary that meets the system short circuit capability can allow significant arc flash energy reduction
  - Traditional metal-clad switchgear with vacuum circuit breakers
  - Metal-enclosed vacuum breakers
  - Padmounted switchgear with VI's
  - Vacuum reclosers
- Any type of relay protection can be utilized on the secondary
  - Simple 50/51
  - Multifunction protective relay

Transformers with integral VIs and simple 50/51 relay are the most cost effective option available.

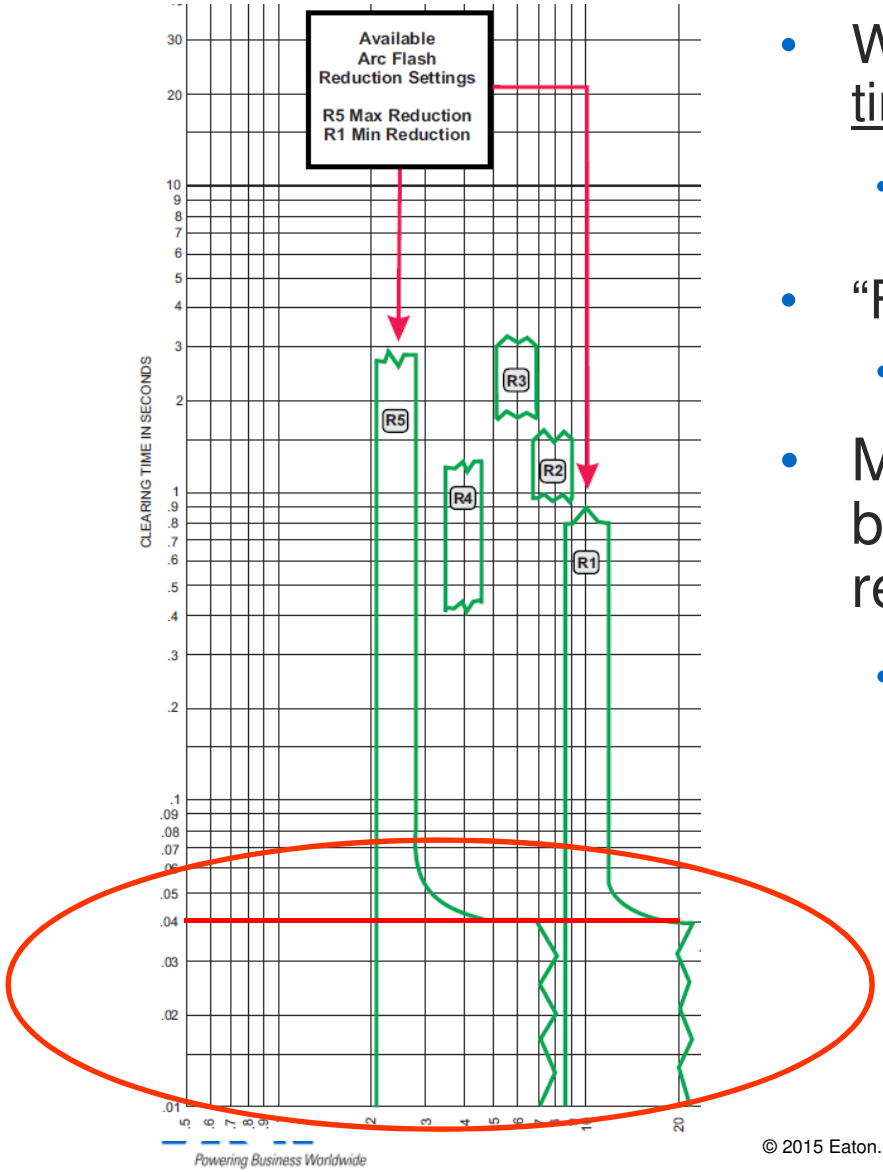
Actually saves $$$ over "traditional" switch and fuse primary and increases protection!

Existing Substation Retrofit Example



- Many existing fused substations with significant arc flash risk problems
- Retrofit with vacuum circuit breaker with Arcflash Reduction Maintenance System (ARMS)
- Utilizes same ARMS protection available on LV power circuit breakers
- Ideal for retrofit applications replacing existing fused primary switches due to compact size and capabilities

Arcflash Reduction Maintenance System (ARMS)



- When activated, breaker total clearing time is reduced to 40 msec!
  - Typical MV Breakers are 50 msec plus relay detection time!
- "Faster than Instantaneous"
  - Bypasses all microprocessor delays
- Medium-voltage vacuum circuit breaker with integral self-powered relay
  - ZSI capability primary-to-secondary

Existing Substation Retrofit Example

MSB–enhanced substation primary and load interrupter switchgear

Reduce the arc flash hazard in your substation featuring the Arcflash Reduction Maintenance System

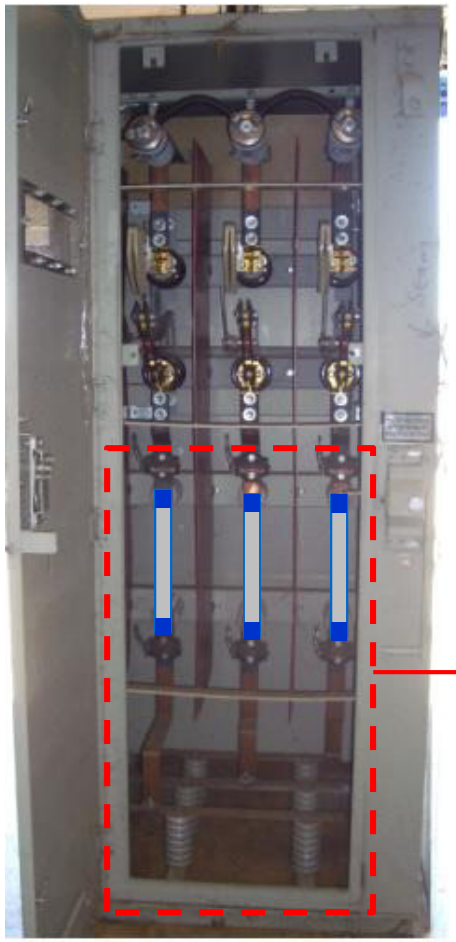
Eaton's MSB (metal-enclosed switch and breaker combination) is an integrated assembly using reliable, cost-effective load interrupter switches in series with VCP-TR vacuum circuit breakers. MSB combines the reliable visible disconnect of a load-break switch with the superior protection capabilities of a fixed-mounted vacuum circuit breaker.

MSB can be used as the primary protection for a single-ended substation (eliminating the need for a secondary main breaker), or it can be used as the primary main device and integrated into a lineup of fused MVS switchgear.

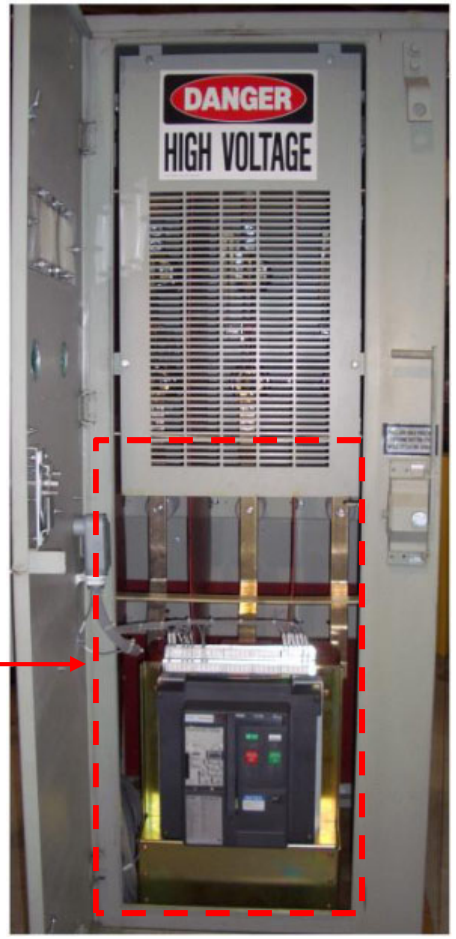
Arc flash hazard reduction

Safety is crucial and standards like NFPA® 70E (Standard for Electrical Safety in the Workplace) have emerged, making it unacceptable for engineers to accept existing or to design new unit substations without considering the impact of arc flash hazards and secondary bus protection. Eaton's MSB delivers an elegantly simple design approach. MSB offers primary transformer protection and secondary bus protection in one 15 kV class primary metal-enclosed assembly.

Arc Flash and PPE



Before



After

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Practical Methods for Reducing Arc Flash Hazards

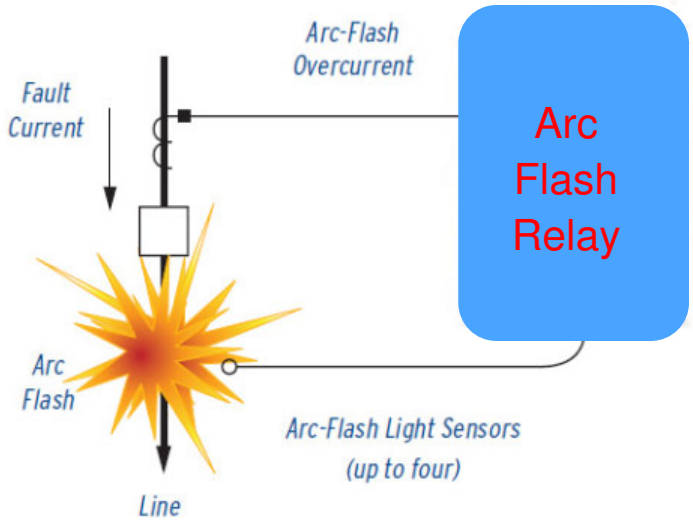
Multiple Settings Groups

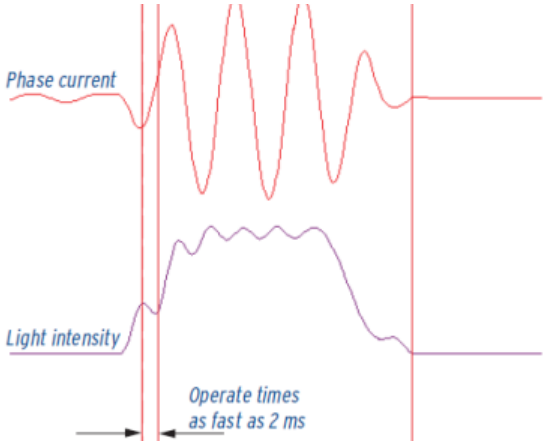
- Similar to LV maintenance switch, only for MV applications
- Used to reduce the trip delay of medium-voltage relays while maintenance (ex. Racking, opening, closing of breakers or auxiliary drawers) is being performed on equipment.
- Most modern microprocessor based relays have multiple settings groups, such as the Eaton E-Series Relays

ARMS using multifunction protective relay – multiple group settings

Arc Flash Light Sensing Relay Protection

- Relays with arc-flash light sensors **and** ct input can be utilized to reduce tripping times
- These can help reduce <u>equipment damage</u>
- These systems do not provide the functionality of arc resistant switchgear for personnel safety





Anatomy of an internal arcing fault – four stages

- Most damage occurs within the first cycle
- Within 10 msec pressure can reach more than 4200 lbs/ft^2
- Pressure wave peak occurs in first ½ cycle
- Multi-cycle protective devices only reduce thermal duration of the event

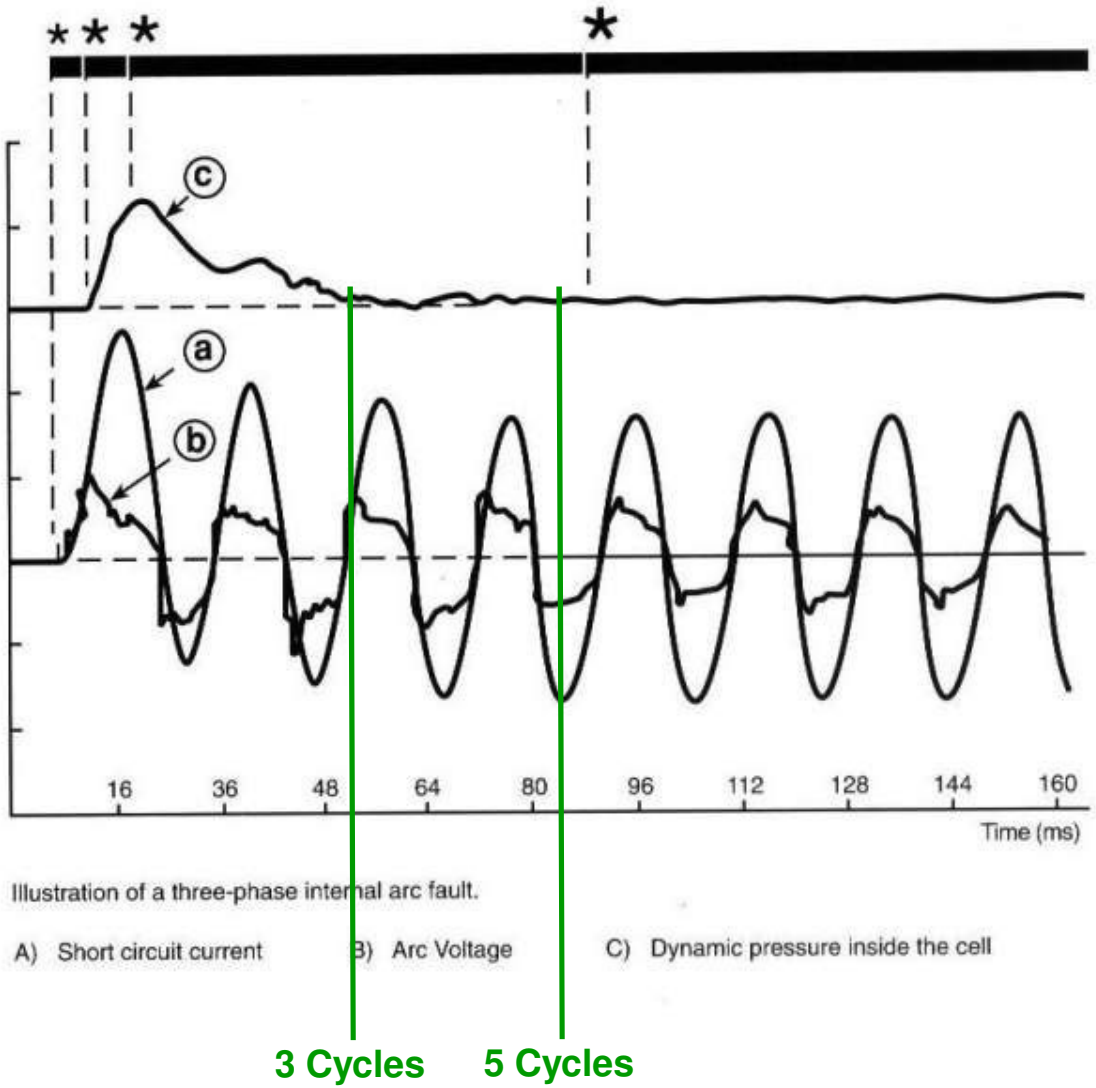
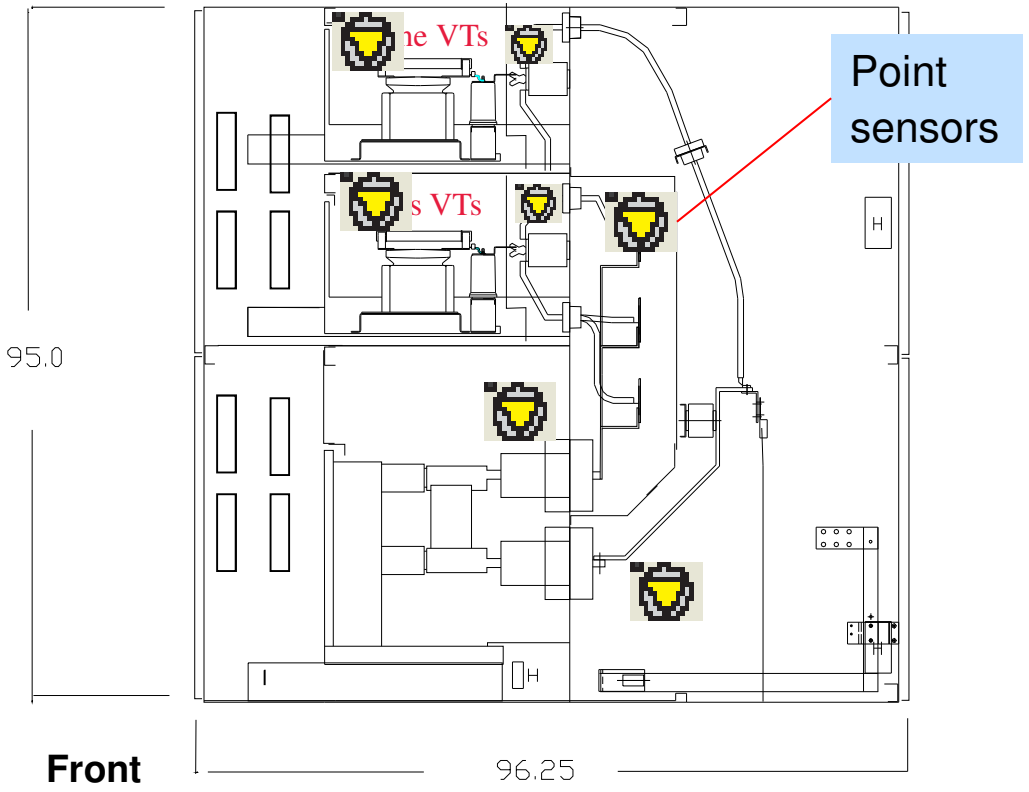


Illustration of a three-phase internal arc fault.

Arc Flash Light Sensing Relay Protection – Point Sensor Locations / Routing

- Installed system must be tested to assure:
  - No “blind spots”
  - No nuisance operation from “good arcs” from protective devices – LV in particular
- Retrofits on untested systems provide a false sense of security
- Sensors utilizing glass fiber optic cables are fragile
  - Extreme care needs to be taken to avoid breakage
- Fibers can be difficult to terminate across shipping splits.

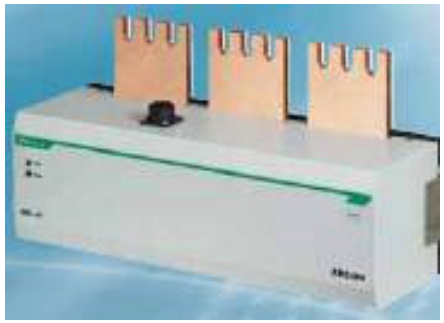


Typical Sectional View

Breaker in lower and vts in upper compartment

Arc extinction technologies

- High current and the flash of light from the internal fault trigger the extinction device and trips the upstream breaker.
  - This technology applies a bolted short across the buses to collapse the voltage and extinguish the arc.
  - These devices haves been a commercially available for LV systems in Europe since 1994.
  - Not popular in the US. Users in the US have concerns about the stresses placed on cables, terminations, and equipment during bolted fault conditions.



Move People Farther Away

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Remote racking systems – why?...

Universal remote power racking devices

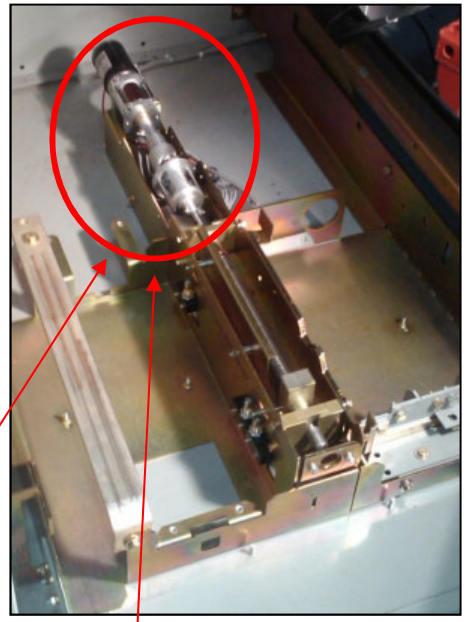
- LV or MV
- Any breaker – multiple manufacturers
- 2 high MV
- 4 high LV
- Intelligent programmable controllers
  - Torque limited
  - Can count # of turns

Portable product specific remote electrically operated racking devices

Integral motorized racking options for circuit breakers and auxiliary drawers

Personnel safety:

- Allows operator to remain outside the arc-flash zone while racking
- LEDs on pendant indicate positions within the cell
- For new equipment as well as retro-fits
- HMI operation options



Pendant

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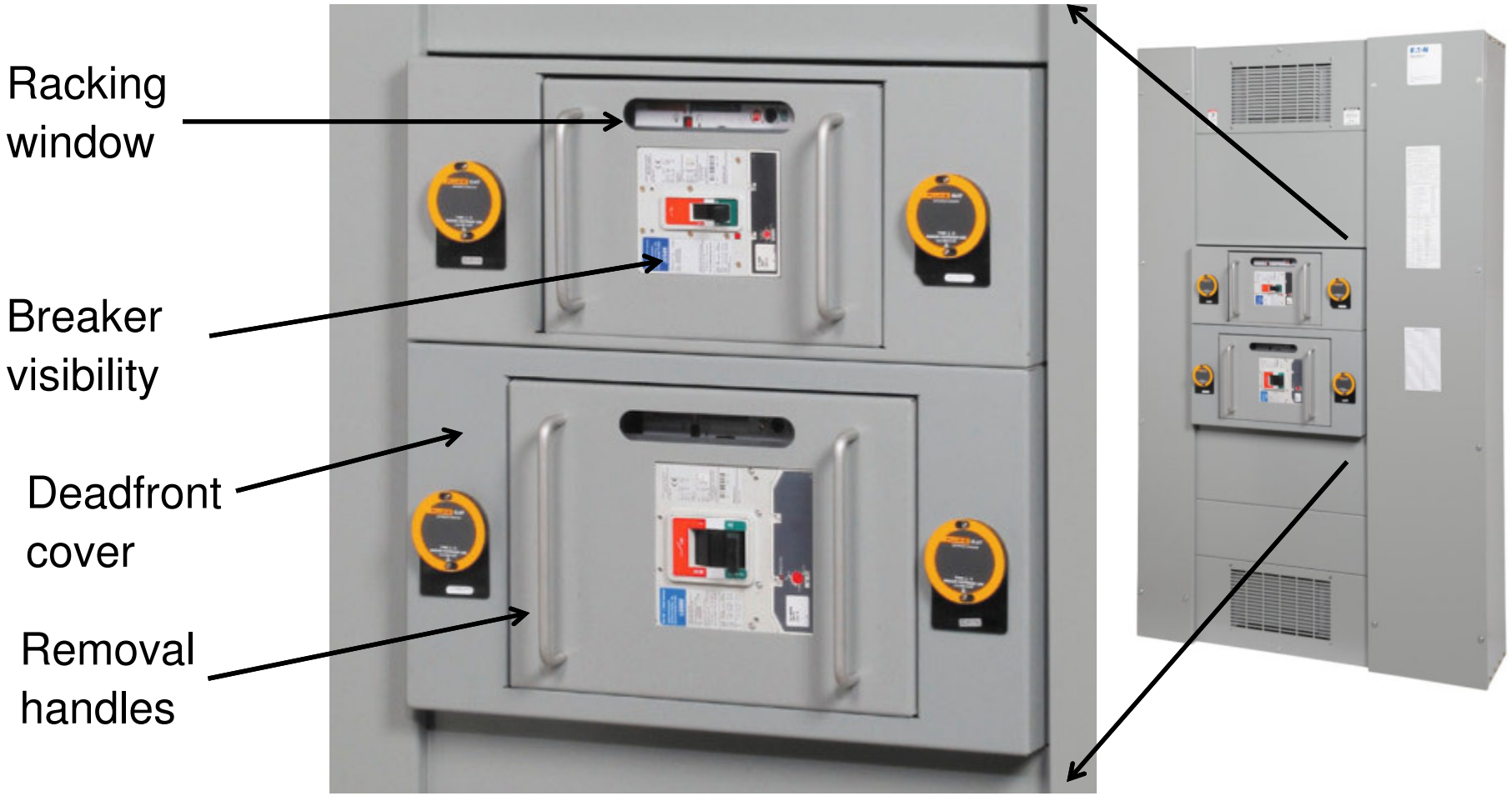
Breaker control switch solutions

ELECTROSWITCH

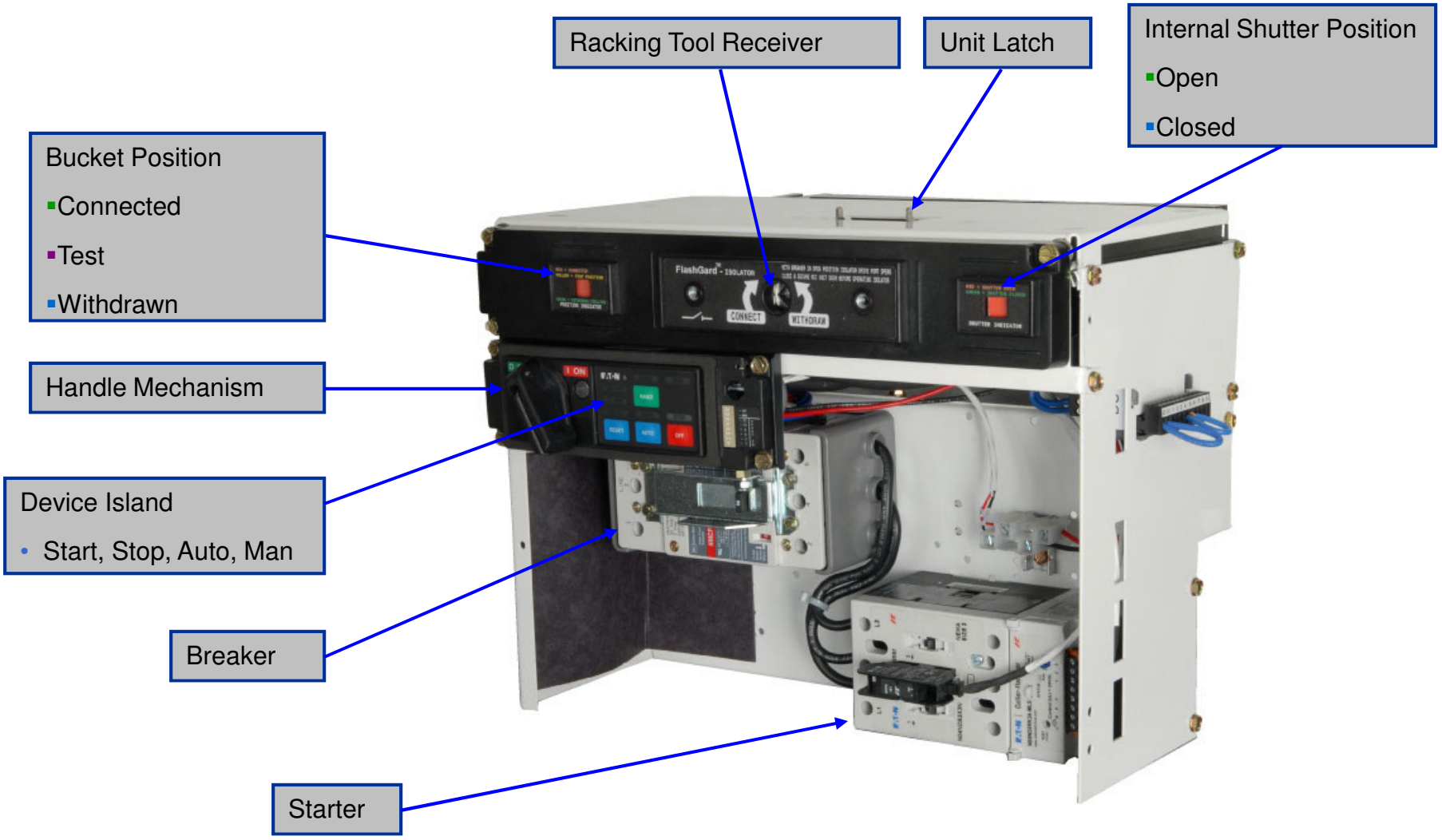
Chicken Switch

Draw-out molded case circuit breaker for panelboards & switchboards

Draw-out molded case circuit breaker with IR window option



MCC buckets with integral levering capability



Minimize The Probability of Faults Occurring

(These techniques do NOT necessarily reduce incident energy or required PPE)

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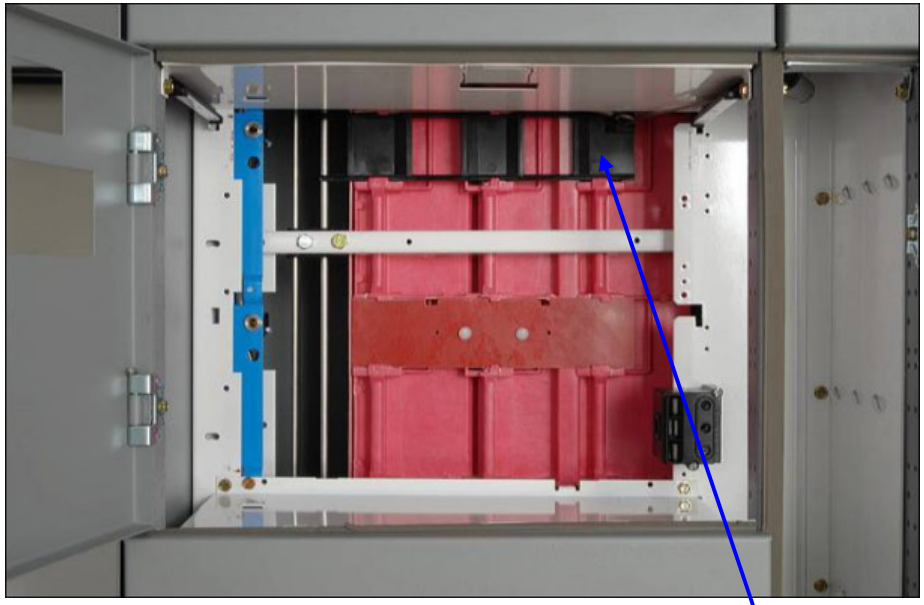
480 volt MCC insulation/isolation options



Automatic Shutters

Isolation Barriers

Insulated Bus

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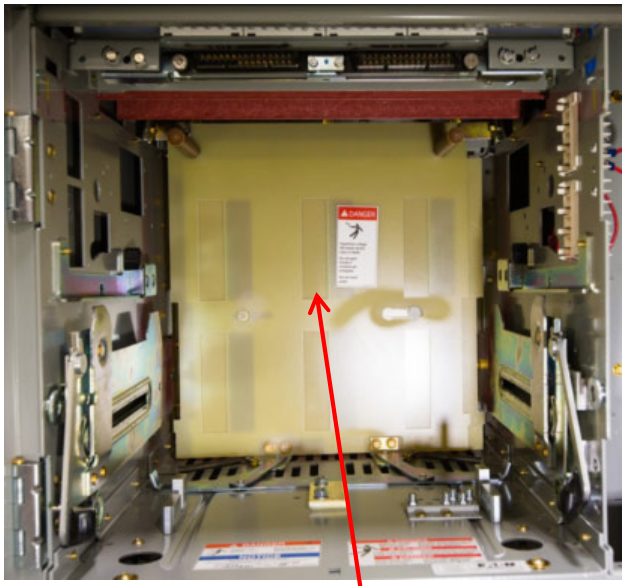
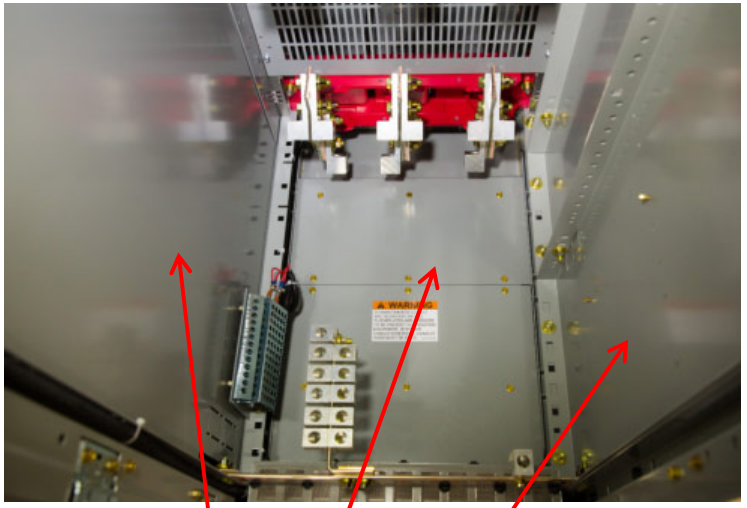
97

LV switchgear isolation options



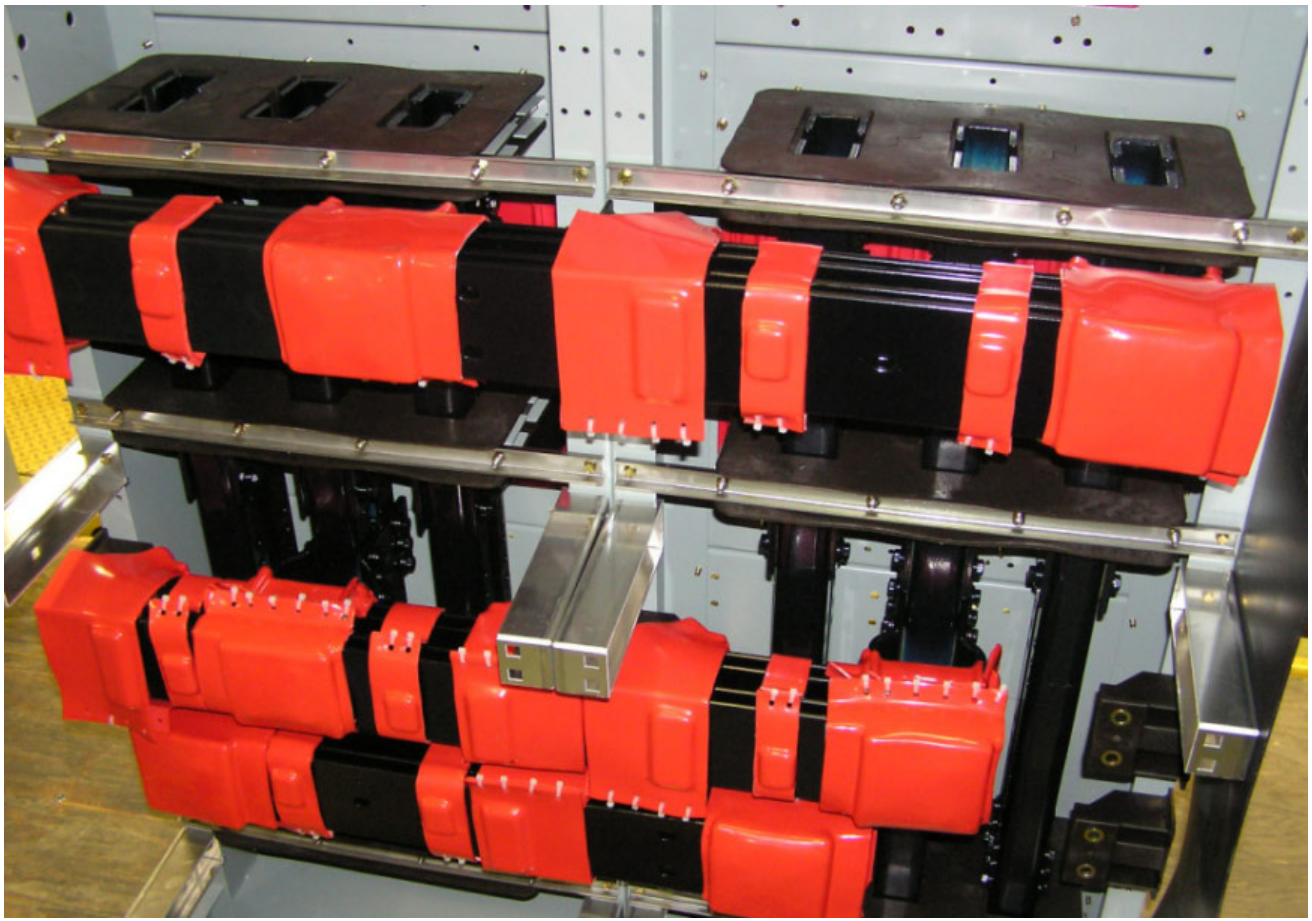
Optional shutters



Optional barriers

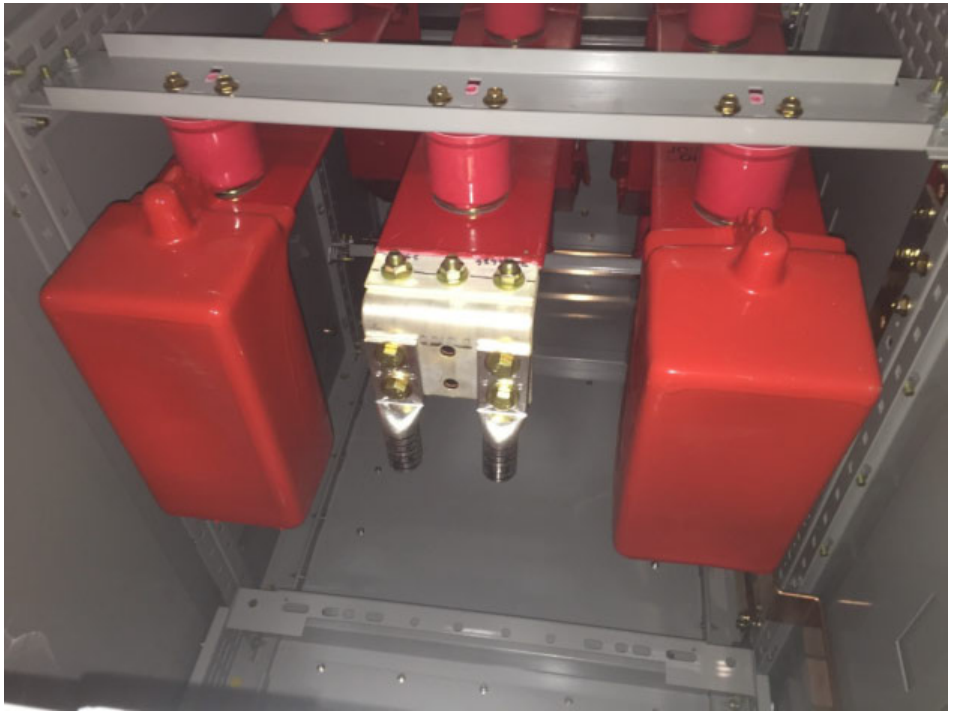
Rodent (?) proofing…

LV switchgear insulated bus options



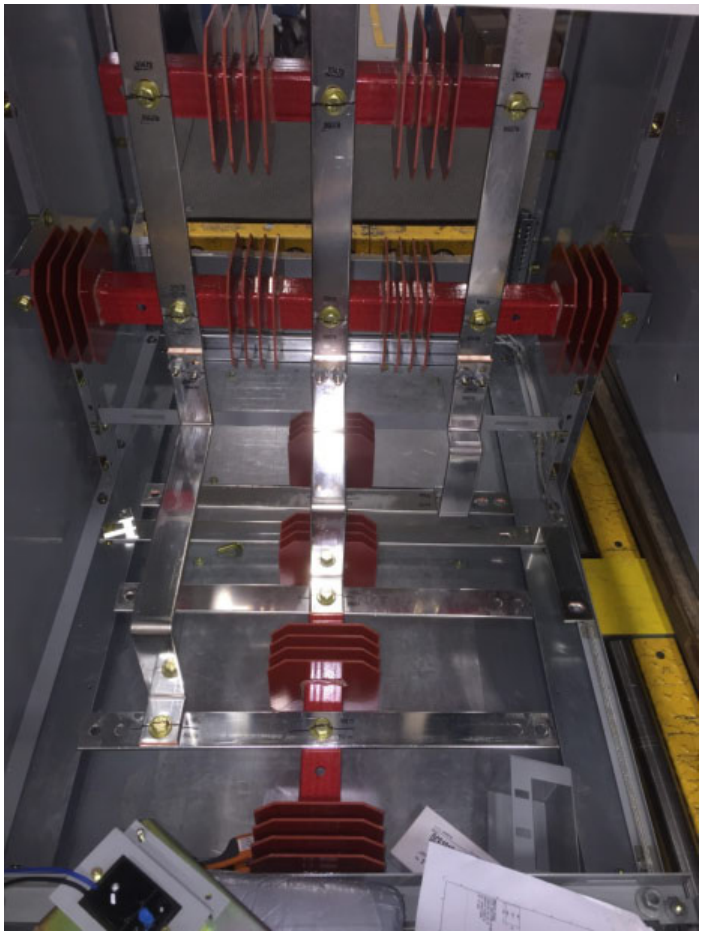
Metal-clad switchgear insulation option

Normal metal-clad cable terminations



Cable termination boot option

Metal-enclosed switchgear insulation option



Normal un insulated metal-enclosed switchgear bus

Metal-enclosed switchgear with insulated bus option

Molded rubber terminations for air terminal chambers

- Deadfront construction
- Preformed insulation system vs. field taping
- Many accessories for grounding, testing, etc.

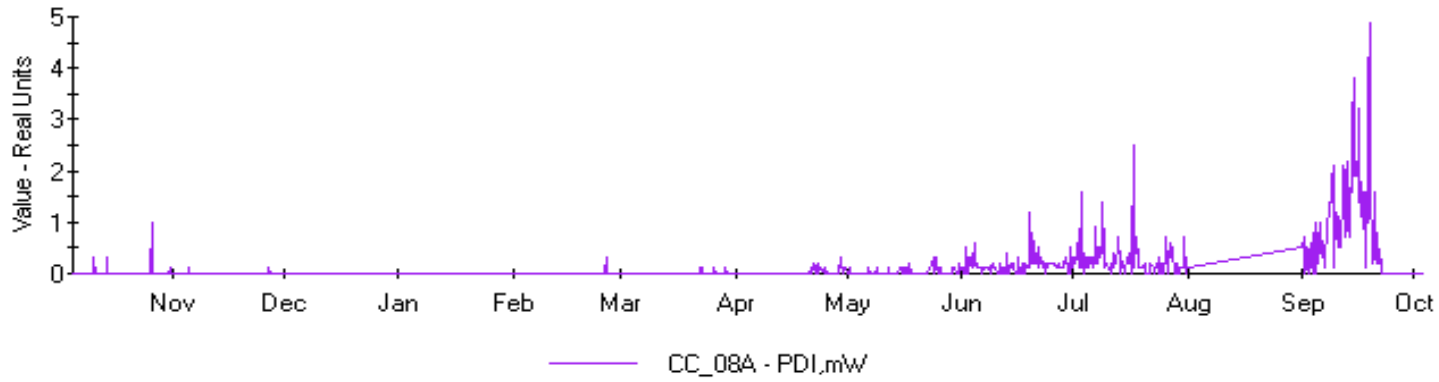
High resistance grounding

- Ground faults are (2 to 70 times) more likely to occur than phase-phase faults
  - Source: IEEE Std 493-1997 (Gold Book), Table 3-30
- Does not reduce arc flash exposure or preclude using PPE
  - Can help reduce the probability of an arcing accident
- Limits ground faults typically to 5 – 10 amperes
- Pulsing contactor allows for fault tracking
- Available for LV or MV
- NOTE – not allowed per NEC for 4-wire systems

Partial discharge (PD) monitors

- Monitor MV insulation integrity
  - Switchgear
  - Generators
  - Motors
- Continuous 24/7
- Online
- Non-destructive

Stop MV switchgear failures



Results of partial discharges

Phase to phase discharges on ring bus

49 MVA generator

Partial discharges on motor stator

Summary: Solutions that reduce arc flash injuries and equipment damage

- Take a System Approach
  - Label Equipment & Minimize Risk
  - 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

Questions?

Thank You!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