Arc Energy Reduction

NEC 240.87 Requirements

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Course Code: CEU243
CEU Value: 0.1 CEU

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Introduction

- Definitions

- NEC requirements

- NFPA 70E requirements

- Methods to reduce clearing time

- Design considerations

- Recommendations

- Resources

Objectives

Upon completion of this presentation you will be able to:

- **Identify:**
    - The NEC requirements for arc energy reduction
    - The NFPA 70E electrical hazard analysis requirement
    - Methods to reduce clearing time
    - Design considerations that should be taken into account

- **Determine how to:**
    - Comply with the 2011 and 2014 NEC requirements
    - Evaluate the various arc energy reduction means
    - Find resources to help with the arc energy reduction design task
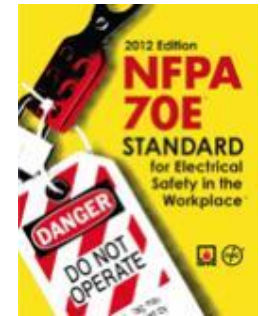
DEFINITIONS

Definitions

- **Arc Flash Hazard**

 A dangerous condition associated with the possible release of energy caused by an electrical arc.

Arc Flash Information

Category 0	Use this information in accordance with applicable OSHA standards, NFPA 70E, and other required safe electrical work practices.

25 inches	Flash Protection Boundary
2 cal/cm²	Max Incident Energy at 18" Working Distance
Category 0	PPE Category (Per NFPA 70E-2004)
208 VAC	Shock hazard when cover is open
42 inches	Limited Approach
Avoid Contact Restricted Approach	Per NFPA 70E-2004
Avoid Contact Prohibited Approach	

Q2C: 12345678
Date: 12/26/07

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Definitions

- **Incident Energy**

  The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. One of the units used to measure incident energy is calories per centimeter squared (cal/cm^2).
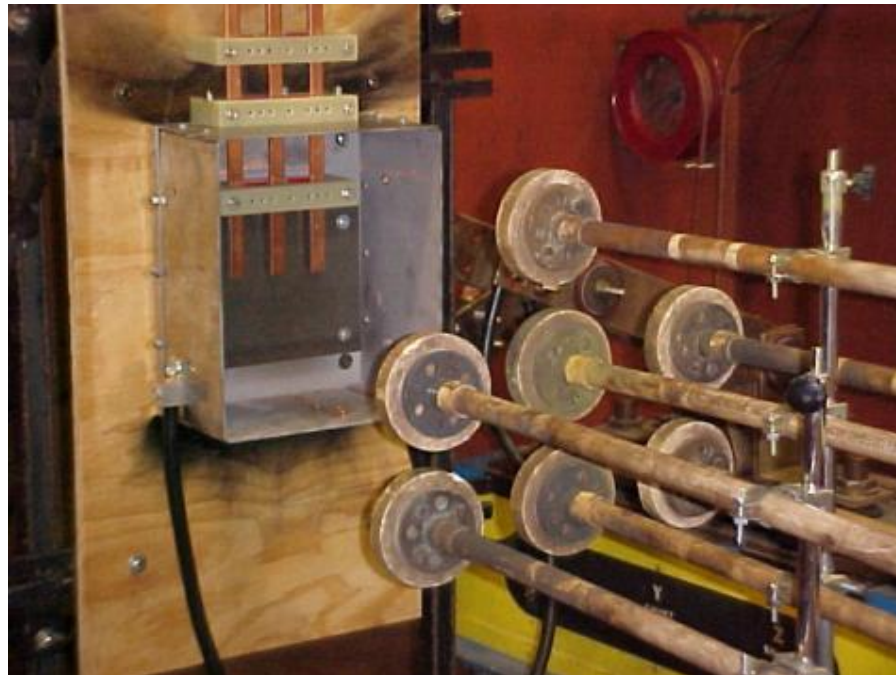
Definitions

- **Arc Flash Incident Energy**
  - The amount of energy is directly proportional to the magnitude of current and its duration

  - Because the arc duration is controllable, it is often the focus of arc flash reduction techniques

  - IEEE 1584 is the most commonly used method for calculating prospective arc flash incident energy

NEC REQUIREMENTS

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NEC Arc Flash Reduction Requirement

240.87 Non-instantaneous Trip. Where a circuit breaker is utilized without an instantaneous trip, documentation shall be available to those authorized to design, install, operate or inspect the installation as to the location of the circuit breaker(s).

Where a circuit breaker is utilized without an instantaneous trip one of the following or approved equivalent means shall be provided:

(A) Zone-selective interlocking

(B) Differential relaying

(C) Energy-reducing maintenance switching with local status indicator

New

Informational Note: An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to no intentional delay to reduce the clearing time while the worker is working within an arc-flash boundary as defined in NFPA 70E, and then to set the trip unit back to a normal setting after the potentially hazardous work is complete.

NEC Arc Flash Reduction Requirement

- **240.87 Non-instantaneous Trip**
  - CMP10 clarified in a panel statement that this requirement pertains only to circuit breakers without an instantaneous trip function, not to circuit breakers that have an instantaneous trip function that has been set to OFF
  - All Square D LV electronic trip circuit breakers have an instantaneous trip function, thus the requirement in this section does not apply to them
    - Note: Those equipped with LSI or LSIG trip functions have an OFF position on the field adjustable instantaneous trip setting switch
    - See Electrical Shortz 0100DB1019

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NEC Arc Flash Reduction Requirement

240.87 Arc Energy Reduction. Where the highest continuous current trip setting for which the actual overcurrent device installed in a circuit breaker is rated or can be adjusted is 1200 amperes or higher then (A) and (B) shall apply.

(A) Documentation. Documentation shall be available to those authorized to design, install, operate, or inspect the installation as to the location of the circuit breaker(s).

(B) 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

Change

NEC Arc Flash Reduction Requirement

- **Summary of changes**
  - Title changed to "Arc Energy Reduction"

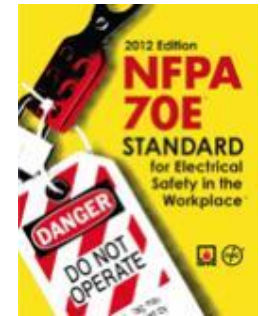 - Requirement changed:
    - From circuit breakers "without instantaneous trip"
    - To "where the highest continuous current trip setting for which the actual overcurrent device installed in a circuit breaker is rated or can be adjusted is 1200 amperes or higher"

  - Added "energy-reducing active arc flash mitigation system"
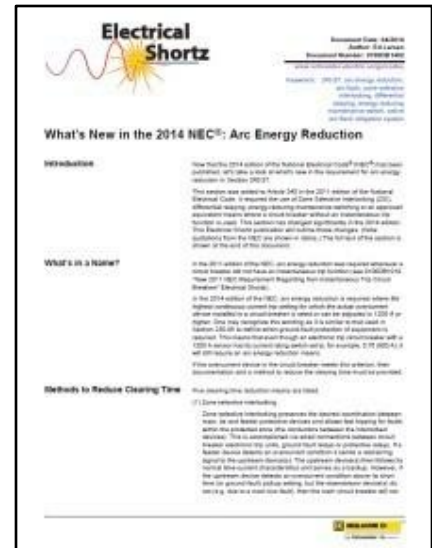
NFPA 70E Requirements

NFPA 70E Requirements

- Section 130.3 requires that an electrical hazard analysis be performed

  - When workers are going to be exposed to energized equipment operating at 50V or more

  - To consist of an evaluation of both shock and arc-flash hazards

# METHODS TO REDUCE CLEARING TIME

Zone-Selective Interlocking (ZSI)

- **What does ZSI do?**

  - Preserves coordination between main, tie and feeder circuit breakers

  - Allows fast tripping for faults within the protected zone

  - Available on LV & MV equipment
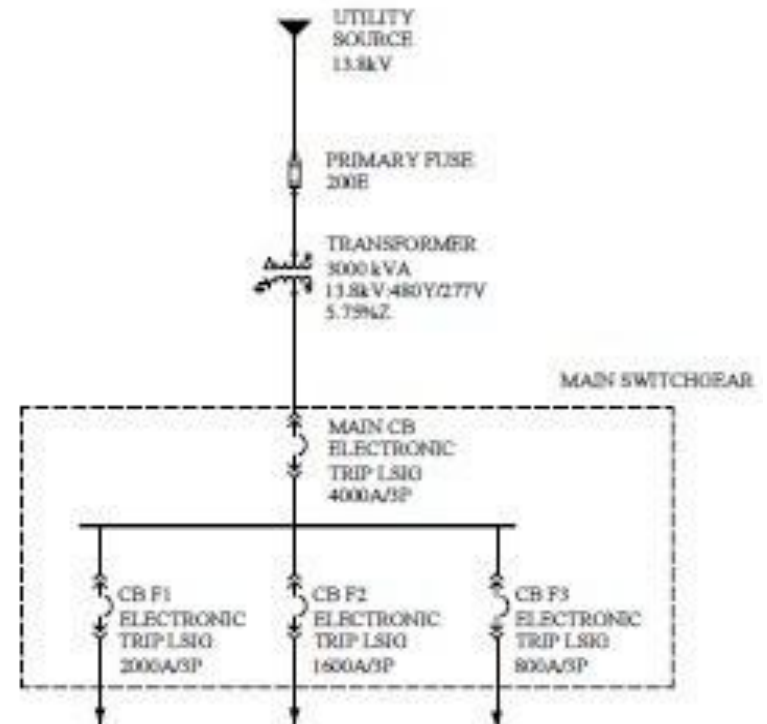
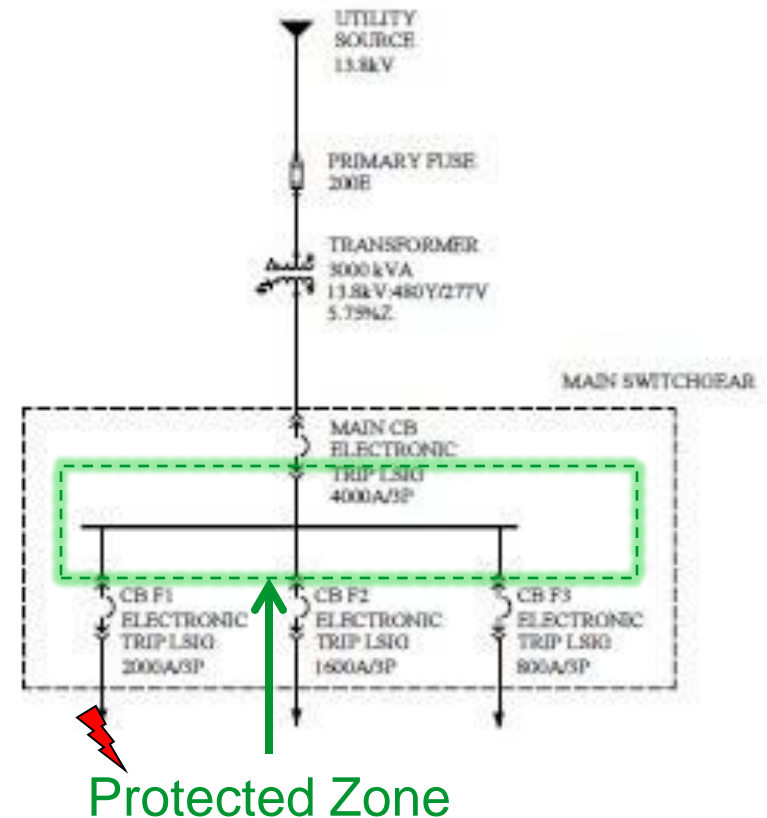# Zone-Selective Interlocking (ZSI)

- **How does it work?**

  - Wired connections between trip units or relays

  - The protected zone is located between the connected devices

Protected Zone
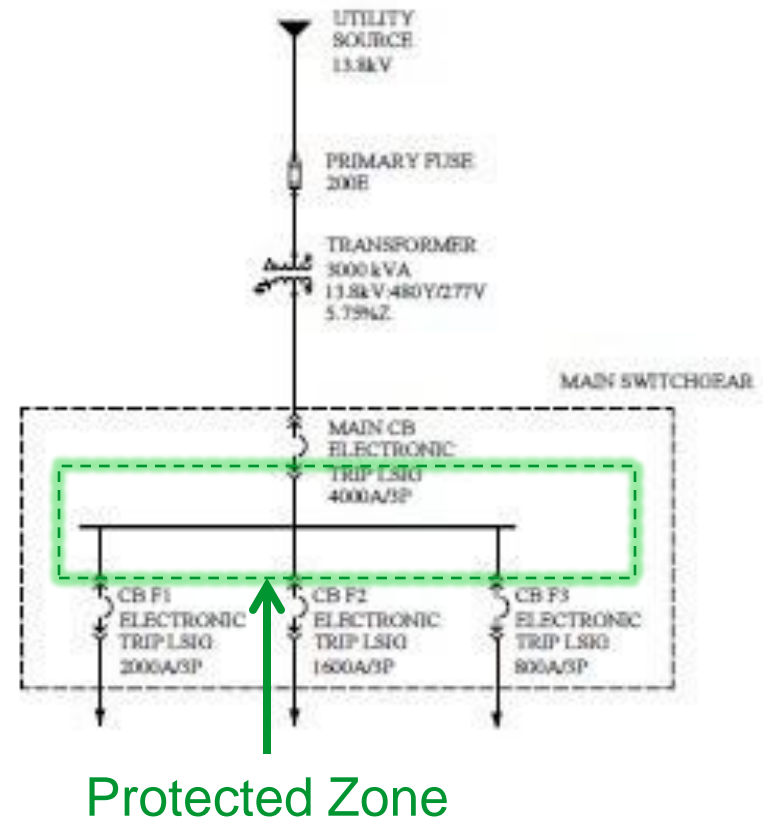
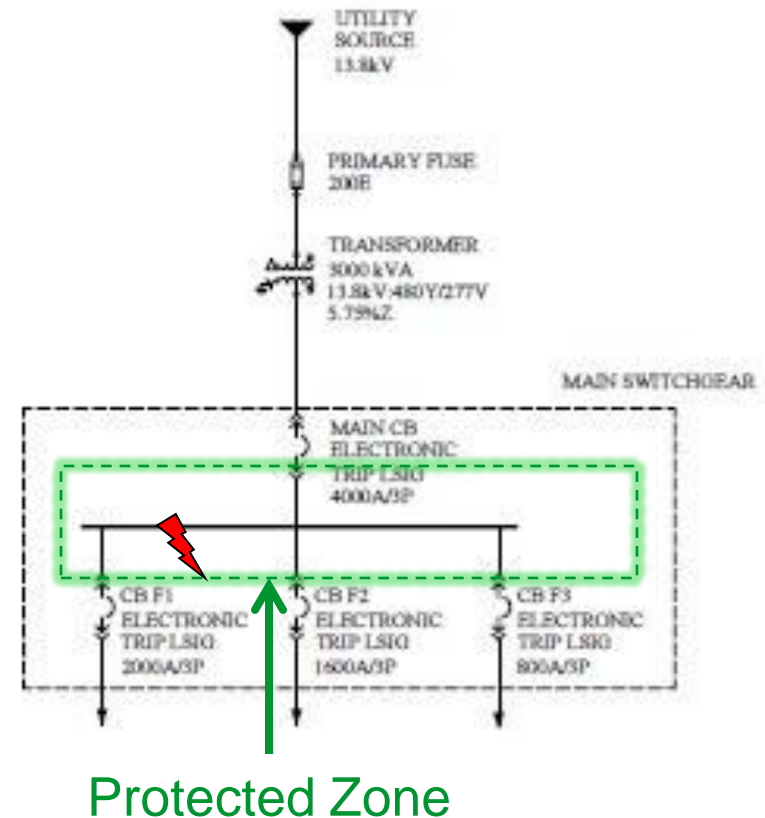# Zone-Selective Interlocking (ZSI)

- **Downstream Faults**

  - If a downstream circuit breaker detects an overcurrent condition it sends a restraining signal to the upstream circuit breaker

  - The upstream circuit breaker then follows its normal time-current characteristics and serves as a backup

Protected Zone

Zone-Selective Interlocking (ZSI)

- **In Zone Faults**
  - If the upstream circuit breaker detects an overcurrent condition above its short time pickup setting…

  - But the downstream circuit breakers do not…

  - Then the upstream circuit breaker will not receive a restraint signal and it will trip with no intentional time delay

Protected Zone

Zone-Selective Interlocking (ZSI)
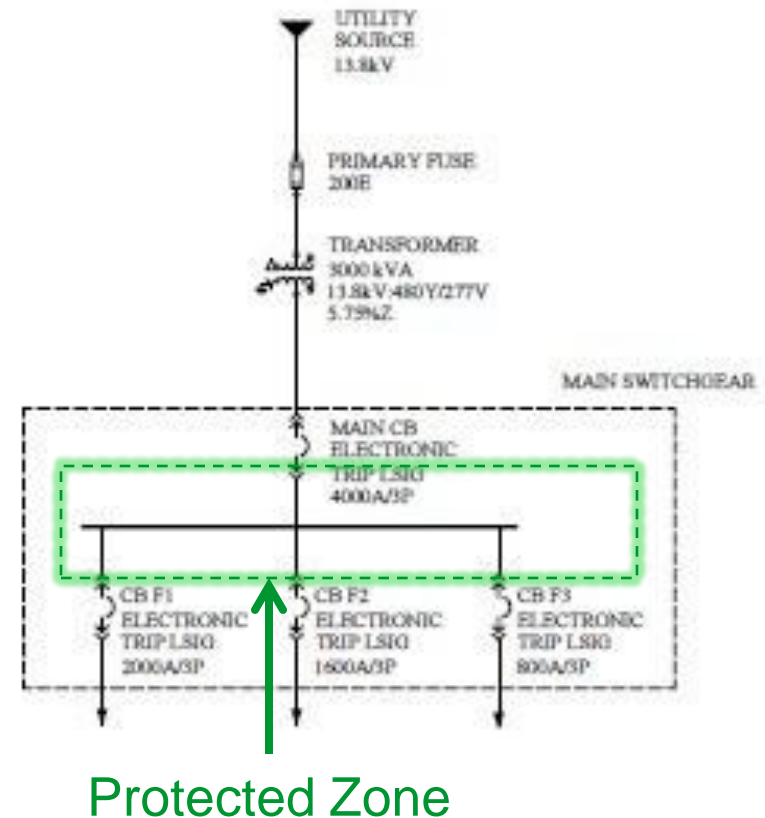
- **Advantages**
  - Fast clearing of faults without sacrificing coordination
  - Automatic - no operator intervention required
- **Disadvantages**
  - Protection only within zone
 - Works only with electronic trip units and relays
- **Caveats**
  - Short time pickup on the upstream device must be set below the prospective arcing fault current


Protected Zone

Differential Relaying

- **What does differential relaying do?**

  - Preserves coordination between main, tie and feeder circuit breakers

  - Allows fast tripping for faults within the protected zone

  - Primarily available on MV equipment

  - Can be applied for both phase & ground fault protection
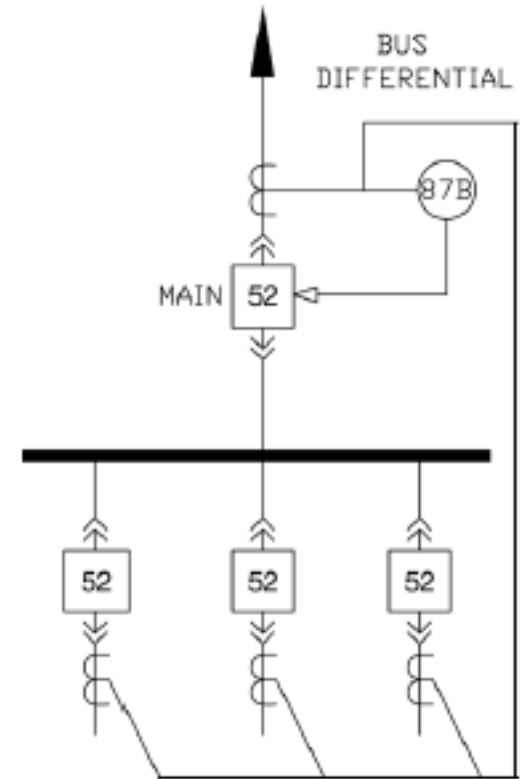
Differential Relaying

- **How does it work?**
  - Relay class CTs are connected to each external connection to the protected bus
  - The CTs are connected such that if all the currents entering the bus equal all the currents leaving the bus, there is no net current flow into the relay
  - A bus fault will cause an unbalance of the incoming and outgoing currents and cause the relay to operate
  - The protected zone is located between the connected CTs

Protected Zone
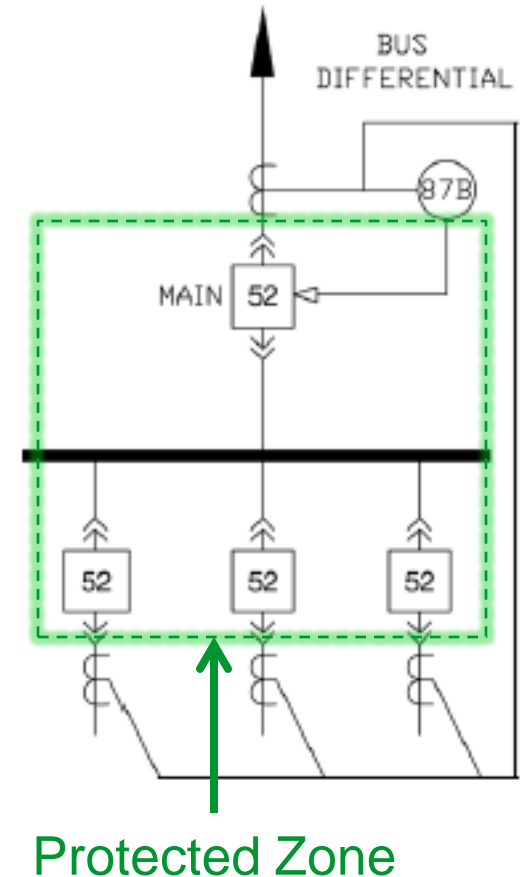
Differential Relaying

- **Advantages**

  - Very sensitive to bus faults but immune to load inrushes or pass-through faults

  - Fast clearing of faults without sacrificing coordination

  - Automatic - no operator intervention required


Protected Zone
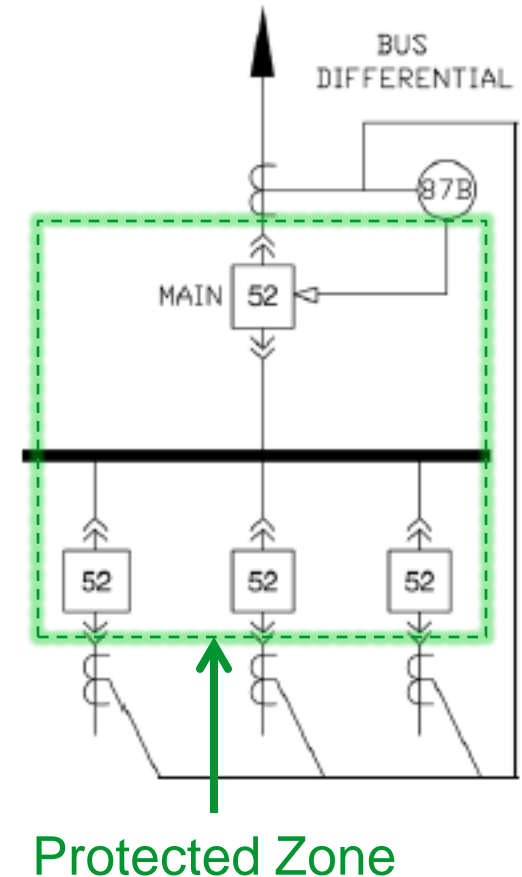
Differential Relaying

- **Disadvantages**
  - Less common at LV due to the increased space requirements for relay class CTs, differential protective relays and additional wiring complexity
  - The costs associated for LV differential relaying protection are also substantial when compared to the cost of the base equipment
- **Caveats**
  - CT saturation in LV applications may limit use

Protected Zone
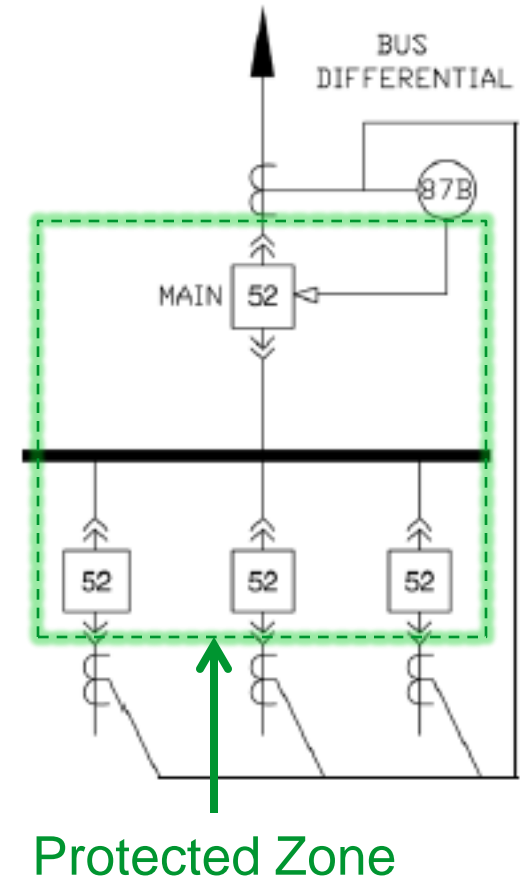
Energy-Reducing Maintenance Switching

- **What does energy-reducing maintenance switching do?**

    - An energy-reducing maintenance switch allows a worker to reduce the clearing time of a circuit breaker while working within an arc-flash boundary

Energy-Reducing Maintenance Switching
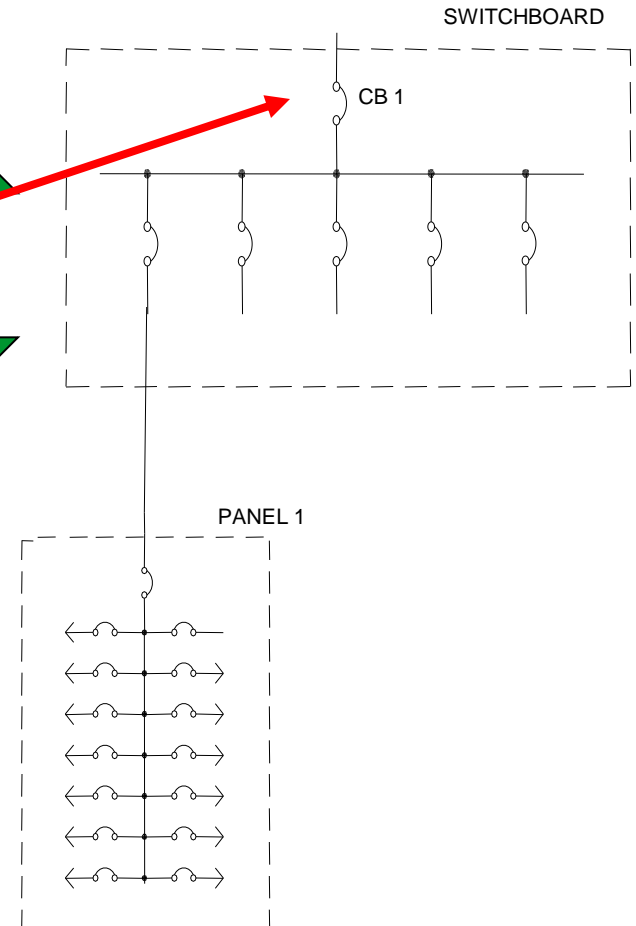
- **How does it work?**
  - The switch may be connected to a circuit breaker or a protective relay

  - The switch may…
    - Lower the instantaneous pickup setting
    - Utilize a faster acting instantaneous trip function
    - Activate an alternate set of trip settings

  - The "switch" may be a lockable switch, proximity sensor or communications system

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# Energy-Reducing Maintenance Switching

- **Advantages**
  - Simple

  - Protection zone may extend beyond the next downstream OCPD
    - Switch located here

    - Protected zone

    - Protection *may* extend here

SWITCHBOARD

CB 1

PANEL 1

Energy-Reducing Maintenance Switching

- **Disadvantages**
  - Requires additional steps in the live work procedure

  - Requires operator intervention in order to work

  - May compromise coordination

  - Will the maintenance person remember to turn the switch ON and OFF?

Energy-Reducing Maintenance Switching

- **Caveats**

  - Reduced instantaneous trip setting must be below the prospective arc fault current

  - Extension of the zone of protection depends on the prospective arc fault current downstream with respect to the instantaneous trip setting

SWITCHBOARD

CB 1

PANEL 1
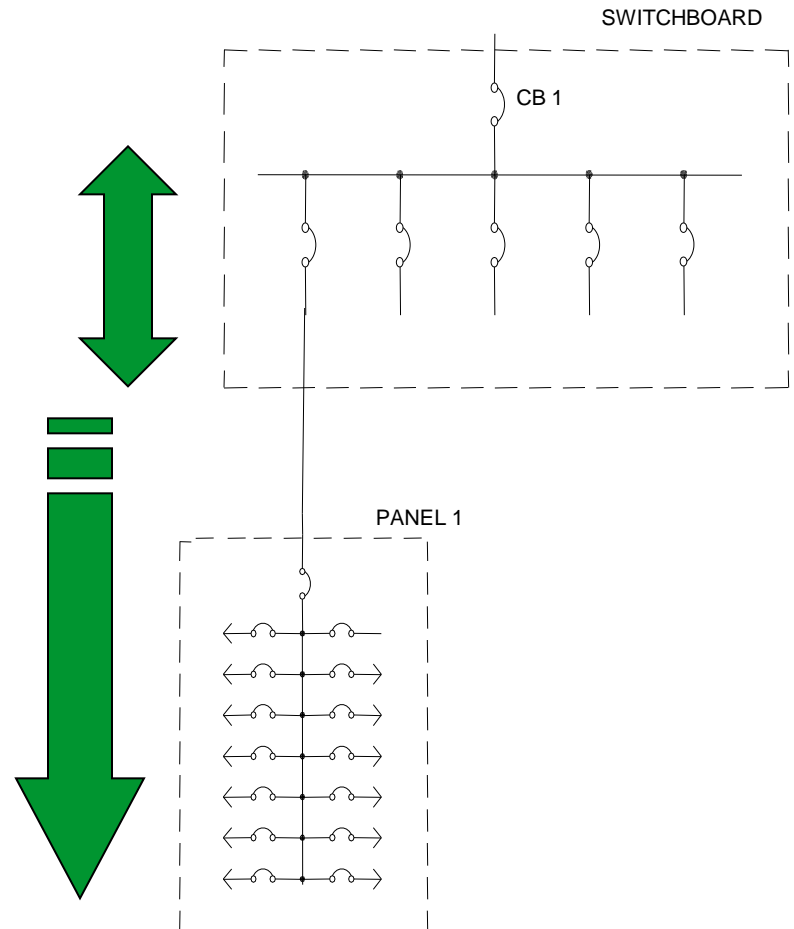
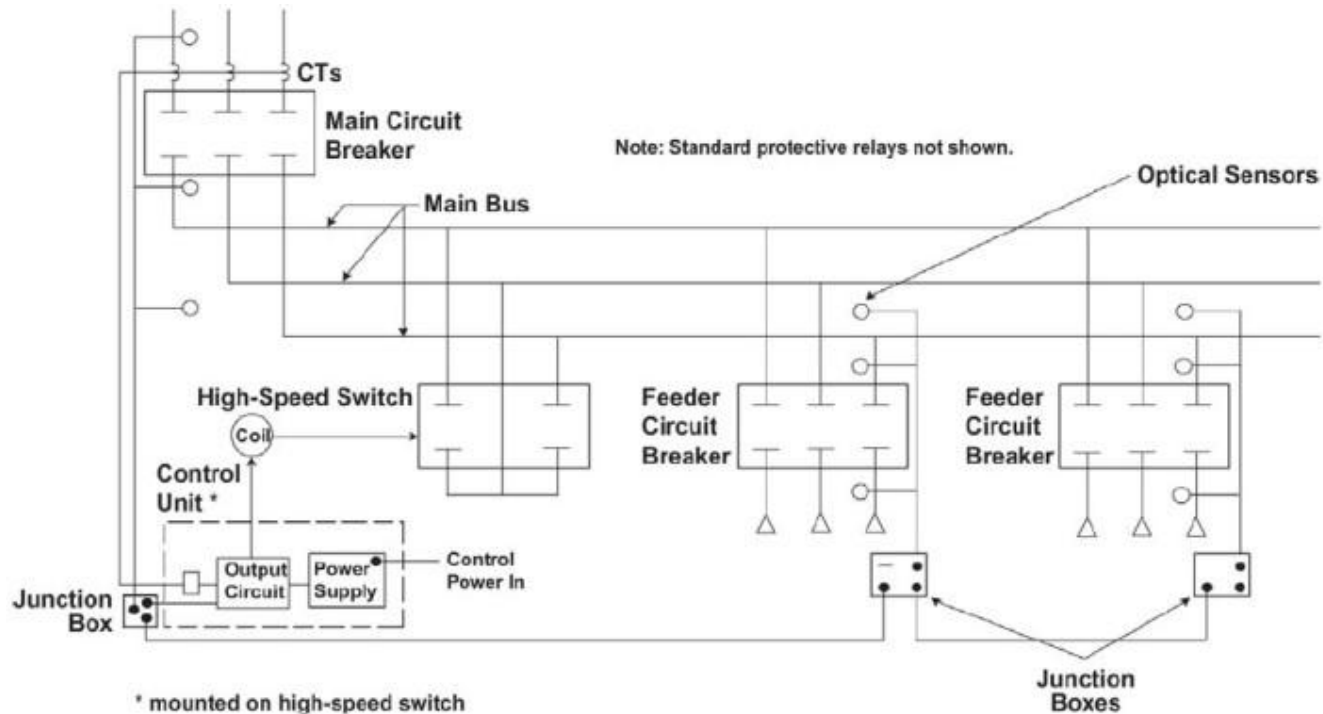# Energy-Reducing Active Arc Flash Mitigation System

- **What does an active arc flash mitigation system do?**
  - Detects an arc flash and reduces the arc energy by…

    - Interrupting the flow of current with no intentional delay, or

    - Transferring the current flow to an alternate path

Energy-Reducing Active Arc Flash Mitigation System

- **How does it work?**
  - A relay senses the flash of light caused by the arc combined with the simultaneous increase in current (or other inputs)
  - The relay closes a high speed crowbar switch or similar device

Energy-Reducing Active Arc Flash Mitigation System

- **Advantages**
  - Automatic - no operator intervention required
  - Can reduce the amount of damage that the equipment itself sustains during the arcing fault event
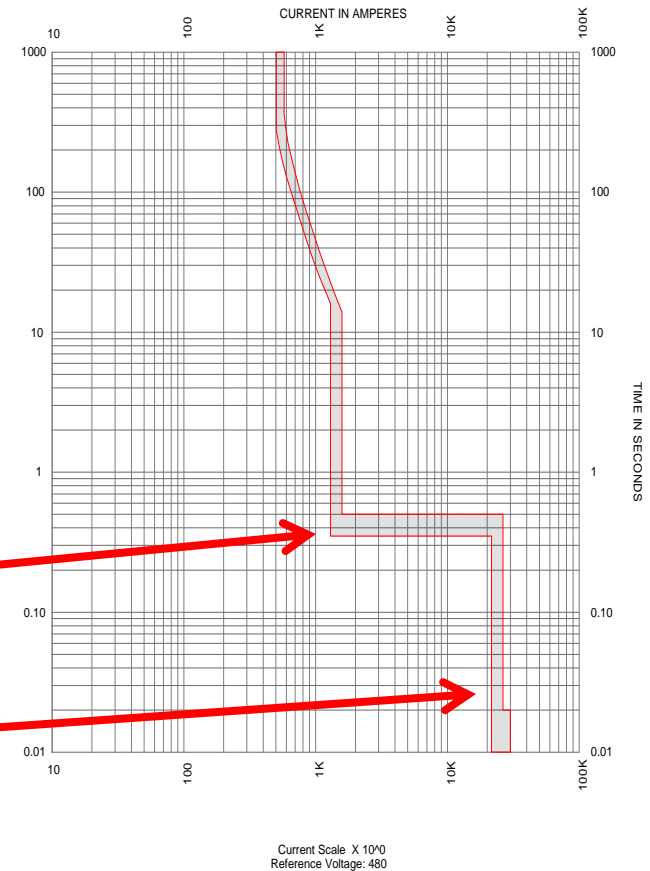
- **Disadvantages**
  - Cost
  - Space Required

Approved Equivalent Means

Instantaneous Trip

- The instantaneous trip on a circuit breaker should be considered an approved equivalent means if it is set below the prospective arc fault current

- It could be a…
 - Field adjustable instantaneous trip

  - Fixed instantaneous override trip

CURRENT IN AMPERES

TIME IN SECONDS

Current Scale X 10^0
Reference Voltage: 480

Approved Equivalent Means

Instantaneous Trip

- **Advantages**
  - Nothing extra to buy
  - No additional space required
  - Protection zone may extend beyond the next downstream OCPD
    - Instantaneous located here
    - Protected zone
    - Protection *may* extend here
  - Automatic - no operator intervention required

SWITCHBOARD

CB 1

PANEL 1

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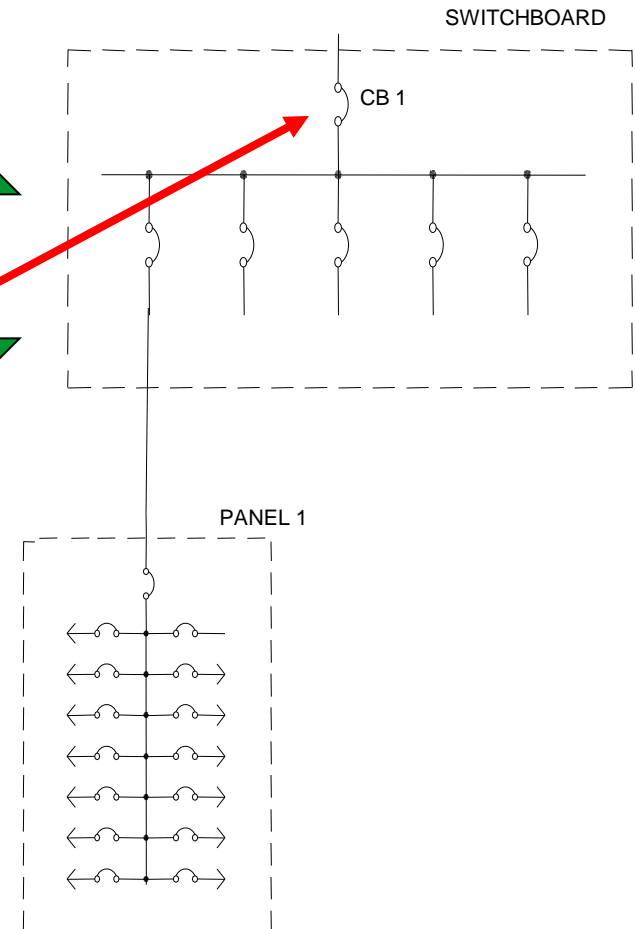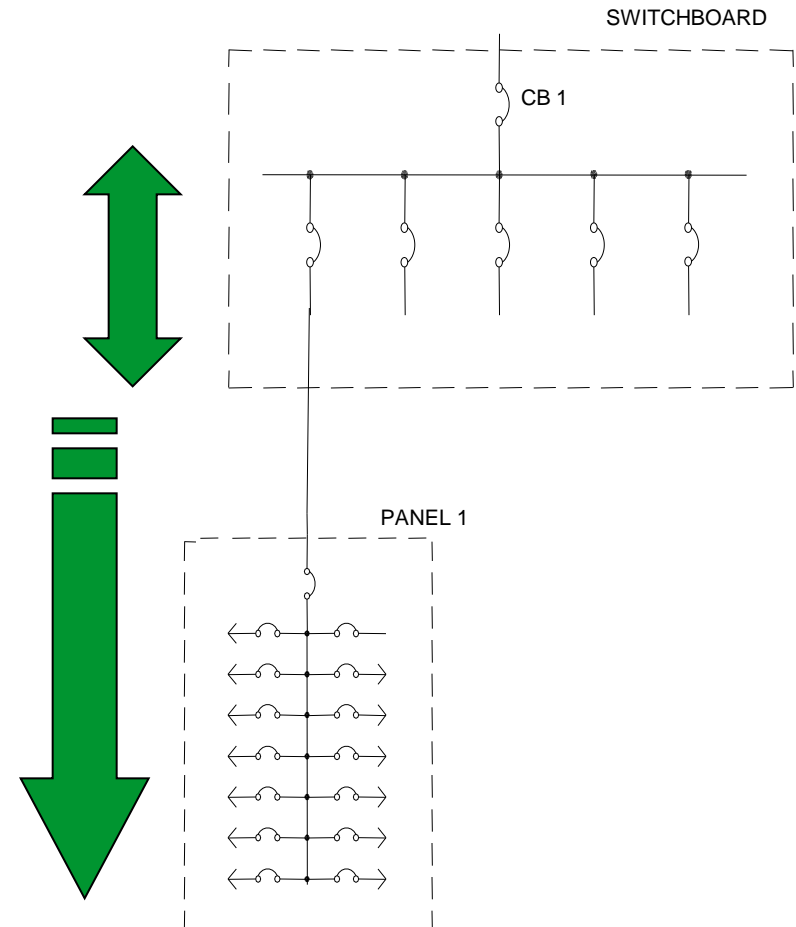
Approved Equivalent Means

Instantaneous Trip

- **Disadvantages**
  - May compromise coordination

- **Caveats**
  - Instantaneous trip setting must be below the prospective arc fault current
  - Extension of the zone of protection depends on the prospective arc fault current downstream
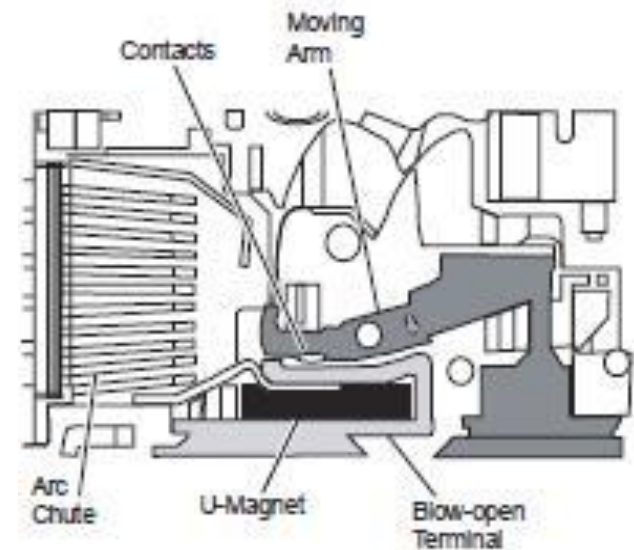
SWITCHBOARD

CB 1

PANEL 1

Approved Equivalent Means

Masterpact Low Arc Flash Circuit Breakers

- **What do they do?**
  - Open quickly in the event of an arc fault

- **How do they work?**
  - The blow-off current path opens the contacts quickly

Approved Equivalent Means

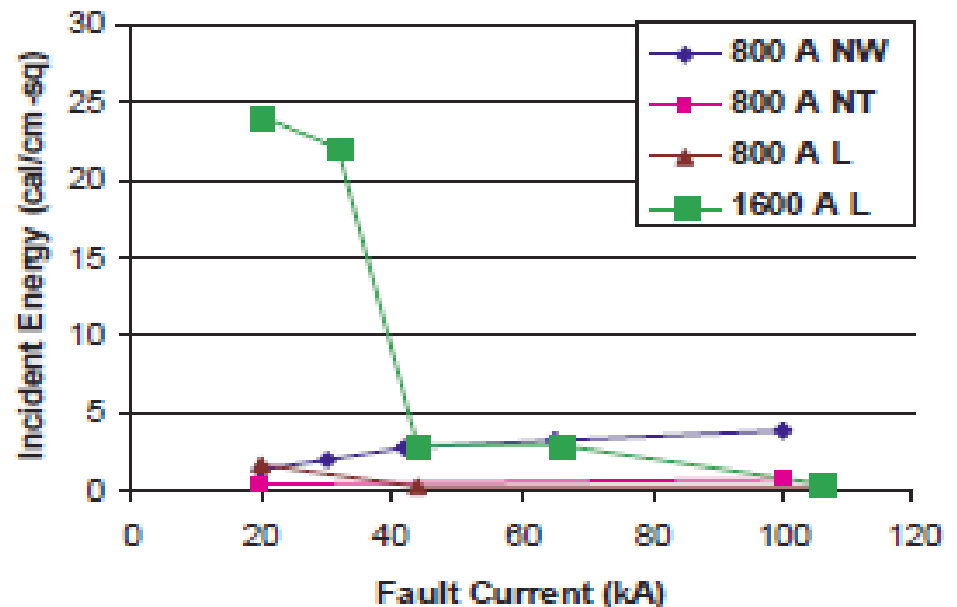**Masterpact Low Arc Flash Circuit Breakers**

- **Advantages**
  - Nothing extra to buy
  - No additional space required
  - Automatic - no operator intervention required

- **Disadvantages**
  - May compromise coordination

Incident Energy Values for Masterpact NW and NT and Circuit Breakers with Class L Fuses

Chart legend:
- 800 A NW
- 800 A NT
- 800 A L
- 1600 A L

Y-axis: Incident Energy (cal/cm -sq), 0 to 30
X-axis: Fault Current (kA), 0 to 120

Approved Equivalent Means

Transfer Trip

- aka virtual main

- CTs located on the secondary side of the transformer feed a relay

- Relay output connected to the device on the primary side of transformer
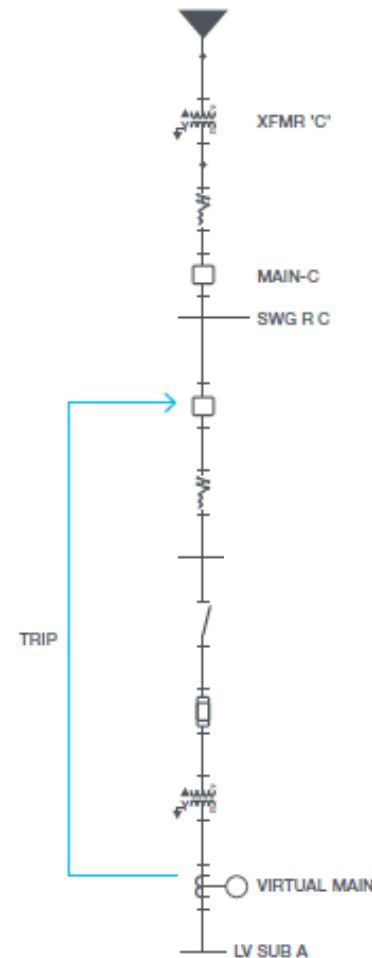
Approved Equivalent Means

- Arc flash reduction methods that should **NOT** be considered an approved equivalent means

  - High Resistance Grounding
    - Can reduce the phase to ground hazard
    - Cannot reduce the phase-to-phase hazard

  - Arc resistant equipment
    - Can reduce the hazard when covers and doors are in place
    - Cannot reduce the hazard when covers are removed and doors are open
    - *Note: internal damage can be significant*

Meeting the Code

- Meeting the letter of the Code

  - It is relatively easy to meet the letter of the 240.87 requirements without actually achieving a real improvement in worker safety

- Meeting the spirit of the Code

  - Achieving a real improvement in worker safety it what 240.87 is all about, but that requires some carefully thought out engineering

DESIGN CONSIDERATIONS
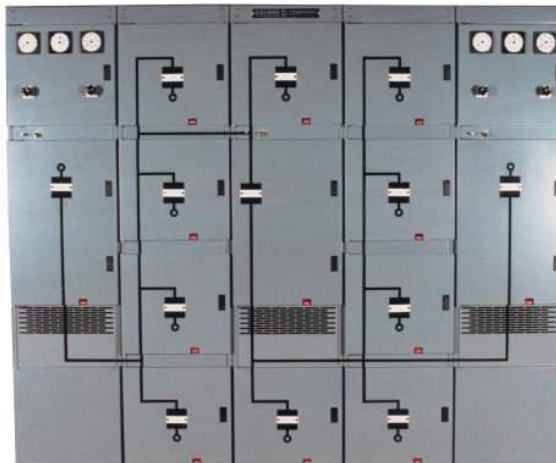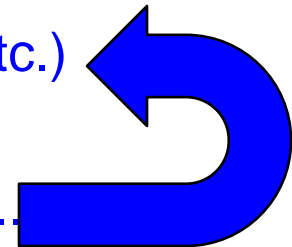
Design Considerations

- Arc-flash mitigation involves taking steps to minimize the level of hazard associated with an arc-flash event

  - Reduce the potential severity of an incident and/or…

  - Reduce the likelihood (risk) that an incident will occur

Design Considerations

ANSI Z10-2012 Occupational Health and Safety Management Systems

- Defines a hierarchy of mitigation controls as follows, listed from least-to most-effective:
    - Personal Protective Equipment (PPE)
    - Administrative Controls (work policies & procedures)
    - Warnings (including awareness training)
    - Engineering Controls
    - Substitution (of less hazard materials, processes, etc.)
    - Elimination
- Safety by design is always the best approach………….

Design Considerations

Engineering Controls

- Application of products or design techniques to mitigate the arc-flash hazard

- They are considered more effective than PPE because they seek to reduce the degree of hazard

- More effective than administrative controls and warnings because they often do not rely solely on workers following proper procedures and safe work practices

- The "sweet spot" for arc flash mitigation

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Design Considerations

- Per the equations in IEEE Std. 1584-2002, arc flash incident energy varies linearly with time

  - Double the duration of the arcing fault and the available energy doubles

  - Halve the duration and the energy is cut in half

  - Proper selection of overcurrent protective devices that will quickly clear arcing faults from the power system is a powerful mitigation strategy
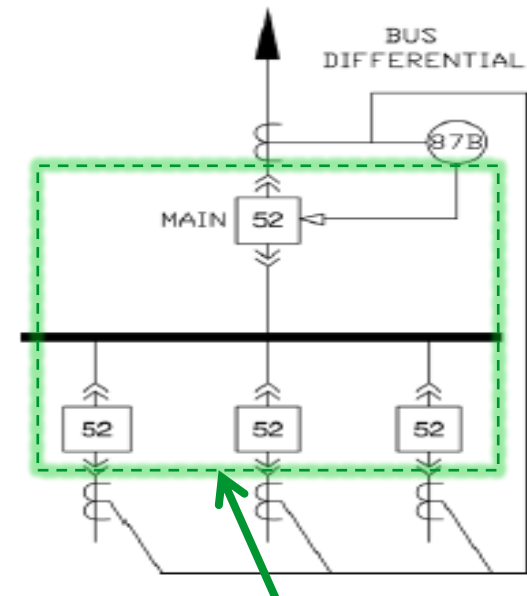
Design Considerations

- **All Means Establish a Zone of Protection**
  - Where is the arc energy reduction required?
    - In the equipment where the reduction means is located?
    - At downstream equipment?
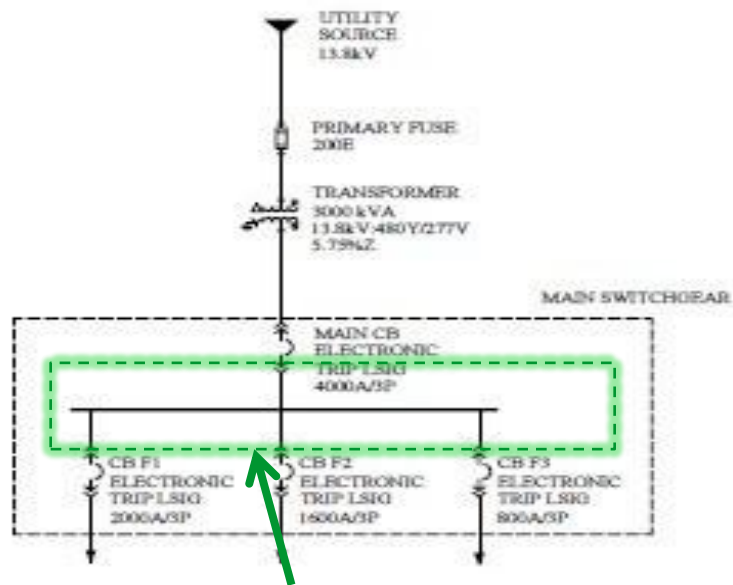
ZSI Protected Zone

Diff. Relay Protected Zone

Design Considerations

- **All Means Establish a Zone of Protection**
  - Where is the arc energy reduction required?
    - In the equipment where the reduction means is located?
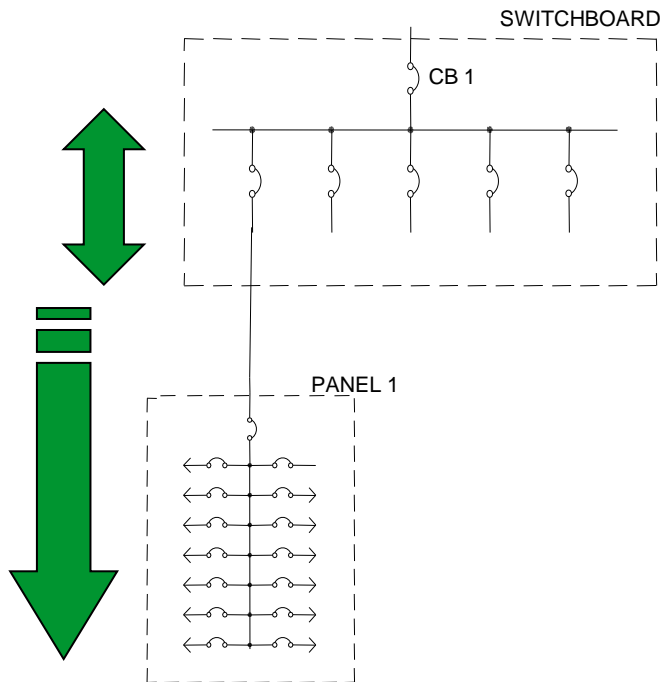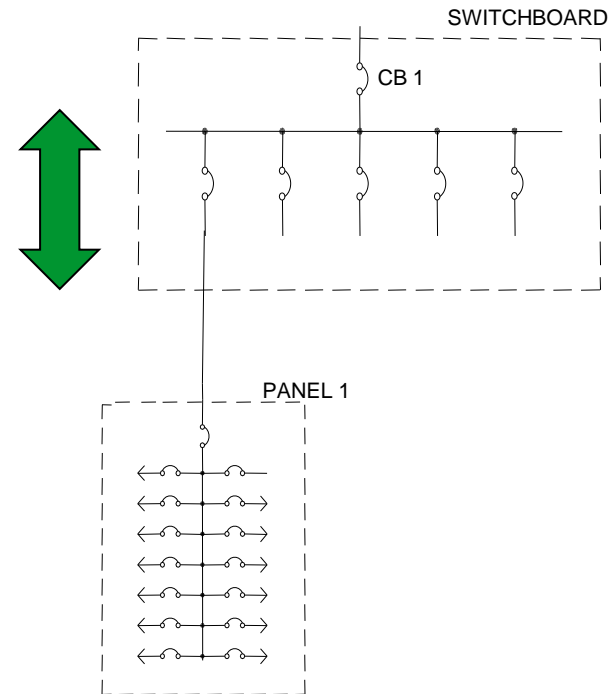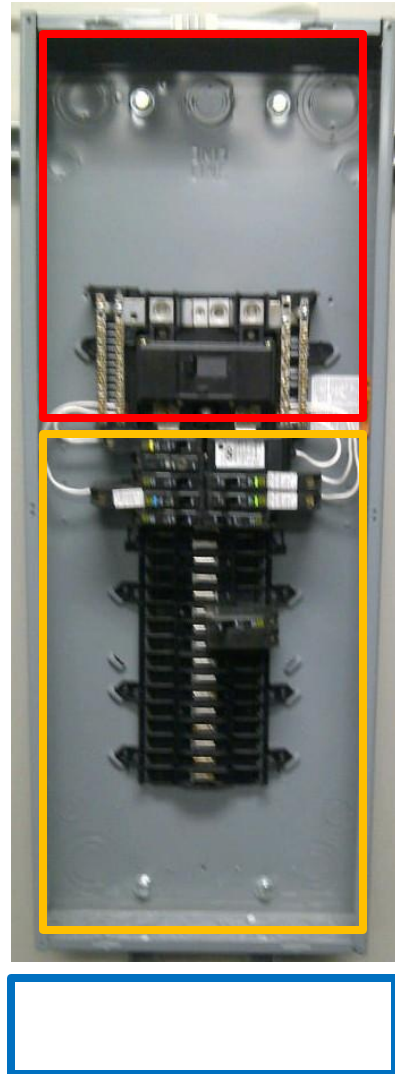   - At downstream equipment?

Maintenance Switch Protected Zone   Active Arc Flash Protected Zone

Design Considerations

- **Will the means really reduce the hazard?**
  - Equipment must be labeled for the arc flash hazard that exists in zone 1
  - Any arc energy reduction means only reduces the hazard in zone 3, unless equipment is compartmentalized

Zone 1 – Line side of main device

Zone 2 – Load side of main device

Zone 3 – Downstream equipment

Design Considerations

- **Equipment**
  - If equipment is group mounted, such as UL panelboards and switchboards, can the means be effectively located on the main device?

- **Zone Selective Interlocking**
  - Short time pickup on the upstream device needs to be set below the prospective arcing fault current at the downstream device

Design Considerations

Maintenance Switching

- Where should the switch be located?
  - At the circuit breaker it controls?
  - At the panel where the live work is to be performed?

- Is it only suitable for reducing the hazard at remotely fed equipment?

- Where should the indicator be located?

- Is it possible to lock the switch in the activated mode?
  - Can the maintenance people use their uniquely keyed padlocks on the switch?
  - Can multiple padlocks be used?
  - If the system can be actuated from more than one location, does locking a switch in one location disable the other locations?

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Design Considerations

Maintenance Switching

- Is a proximity sensor acceptable?
  - Is it lockable?
  - Is inadvertent operation possible?
  - Is motion necessary for activation?
  - Does the equipment have rear or side access? If so, will there be sensors in other locations?
  - What if the equipment to be worked on is remotely located?

- Is activation via a communications system acceptable?
  - Can the function be deactivated remotely <u>while</u> the equipment is being worked on?

Design Considerations

General Considerations

- Will transformer or motor inrushes cause the means to activate?
  - A second coordination study should be done

- For LV equipment, per IEEE 1584 the low end of the short time pickup tolerance band should be no more than 85% of the prospective arcing fault current at the downstream device

- **Labeling**
  - How will the equipment be labeled? With two labels? Will these be confusing?

Recommendations

- **Safety by design**
  - Separately mounted mains
  - Remote operation and racking

- **Conduct an arc flash study**
  - Preliminary
  - Final

- **Effectively use reduction means**
  - Be aware of the protected zone
  - Coordinate design with safety procedures and PPE available or in use at the facility

Resources

- **New 2011 NEC Requirement Regarding Non-Instantaneous Trip Circuit Breakers**
  - Data Bulletin 0100DB1019
  - How to comply with the 2011 NEC requirements

- **What's New in the 2014 NEC: Arc Energy Reduction**
  - Data bulletin 0760DB1402
 - How to comply with the 2014 NEC requirements

- **Arc Flash Reduction Systems—Are They Always a Good Idea?**
  - Data Bulletin 0600DB0901
 - Application concerns that should be considered
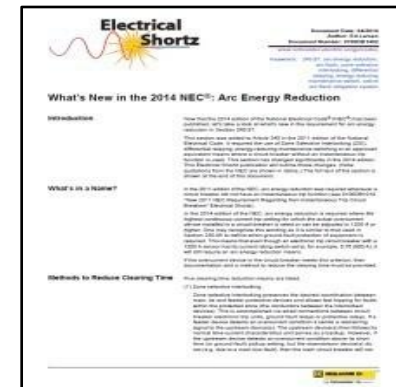
Resources

- **Reducing Fault Stress with Zone-Selective Interlocking**
  - Data bulletin 0600DB0001
  - What it is, how it works, how to design, how to install, how to test

- **Square D Preferred Methods for Arc-Flash Incident Energy Reduction**
  - Data bulletin 3000DB0810
  - Reviews various methods, pros & cons

- **Arc Flash Mitigation**
  - White paper AT327
  - Overview of the subject and reduction means
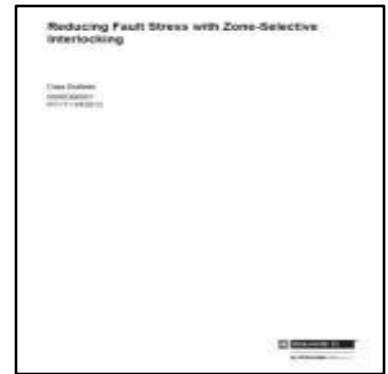
Resources

- **Arc Flash Protection with Masterpact NW and NT Circuit Breakers**
  - Data bulletin 0613DB0202
  - How they work, what they can do

- **Arc Terminator Active Arc-Resistant Switchgear**
  - Handouts 6000HO0902 & 6055HO0101
  - How it works, how it is installed, what it can do

- **Arc Flash: Solutions For Electrical Workplace Safety**
  - Brochure 0613BR0302
  - Overview of Square D AF solutions & services
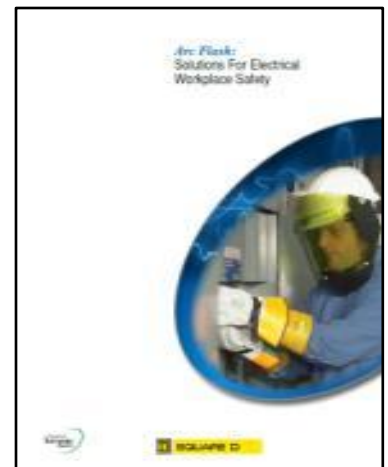
Questions???

Thank you!!!

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