Arc Flash Mitigation Solutions

Making your Electrical Distribution System a safer place to work

By
Dale Boyd
Services Account Manager – Water Wastewater

SQUARE D
by Schneider Electric

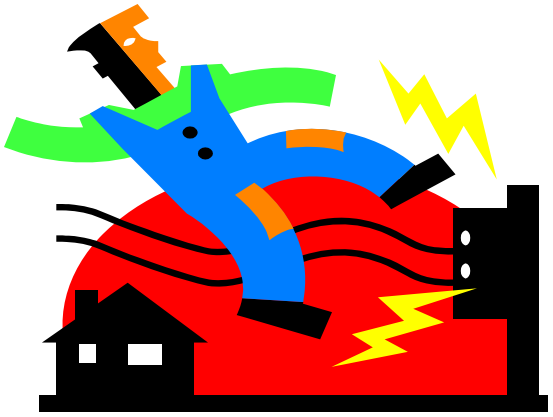
Schneider Electric

Where do we go from here?

- Objectives of Arc Flash Mitigation
- Administrative Controls
- Engineering and Operational Controls
  - Maintenance
  - Design considerations
  - Equipment solutions
- Arc Flash Mitigation Solutions and Strategies

Objectives of Arc Flash Mitigation

- Have fewer faults in the system
- Clear faults more quickly
- Contain energy within the equipment enclosure
- Move workers out of harm's way



Administrative Controls—A Plan for Safety

- Safety Program
- Worker Training
- Arc Flash Studies
- Equipment Labels
- PPE

Engineering and Operational Controls

- History
- Maintenance Considerations
- Design Considerations
- Equipment Solutions

History

- Safety doesn't happen by accident!
- The electrical system should be designed to reduce exposure of workers to injury
- This idea is nothing new, really
  - Design of components has long been intended to minimize the risk of shock or electrocution
  - In coming years, we will probably begin to see more and more products or systems designed to limit exposure to arc flash

Maintenance Considerations

- Poor maintenance can defeat the best design
- Equipment should maintain its integrity
  - Parts falling off: obviously bad
- OCPD should operate within its published tolerance
- Maintenance requirements vary by equipment class
- Specific recommendations:
  - Manufacturer's literature
  - NFPA 70B
  - NETA specifications

Circuit Breaker Maintenance

- Molded-Case Breakers
  - Should be operated periodically
  - Keeps contacts clean, helps operating mechanisms move freely
- LVPCB's
  - Studies indicate LVPCB's not maintained within 5 year period have a 50% failure rate
  - Cleaning, lubrication, exercising
- MV Breakers
  - Should be removed from service and inspected at least once per year

Fewer Faults

- Proper application
  - e.g., NEMA 12 enclosure in dusty environment
- Use of insulated bus
  - Protects against some inadvertent contact?
- Switchgear heaters
  - Reduce moisture inside of equipment
  - Should include provisions for monitoring the circuits to ensure that heaters are operational
    - People recognize this as a good idea, but it is uncommon to see in the field)
- Impedance grounded systems

Clear Faults More Quickly

- Proper selection of protective devices
  - Current-limiting fuses or circuit breakers
  - Size motor and transformer OCPD smaller than maximum level permitted by NEC
- Proper application of protective devices
  - Breaker and relay coordination settings should take arc flash into consideration
  - Use INST protection when possible
- Active solutions (e.g., high-speed fault making)

Contain the Arcing Energy

- We can reduce the probability that a fault will occur, but can we ever eliminate this possibility completely?

- Arc Resistant gear and Arc Terminator gear are both designed to contain the arcing fault and protect workers standing near the equipment
  - Medium-voltage switchgear
  - MV Motor control centers
  - LV Switchgear to come?

Move Workers out of Harm's Way

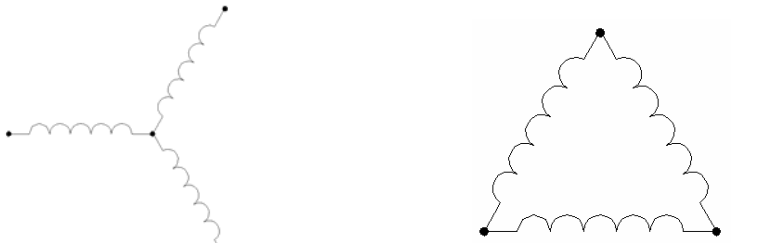
- Incident energy level drops off quickly (approximately as $1/d^2$) as one moves away from the source of the arc
- Remote racking systems
- Remote operation of devices
- IR Inspection Windows

Arc Flash Mitigation Solutions and Strategies

- Impedance grounding
- Device coordination & Arc Flash
- High-speed fault making
- Contain or redirect Arcing Energy
  - Arc-Resistant Construction
- Remote operation/inspection of equipment
- Operational Considerations

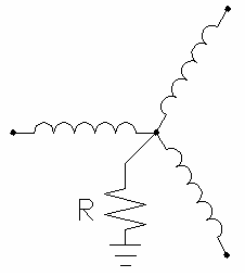
Power System Grounding - Examples

Ungrounded



Solidly Grounded

High Resistance Grounded



Power System Grounding

- Line-ground fault is by far the most common type of fault (est. 70-80%) in power systems
- Many multi-phase arcing faults result from L-G faults that have escalated
- Obvious area for improvement: reduce the number and/or severity of L-G faults on the system
  - Number: maintenance, insulated bus, etc.
  - Severity: grounding methods

Ungrounded System

- No intentional connection to ground
  - **Capacitive coupling**
- Typically delta-connected
- Good news: no fault current for L-G fault
  - **Process not interrupted**
- Unfortunately, there are plenty of other problems:
  - **Sustained L-G overvoltage on unfaulted phases**
  - **Transient overvoltages**
  - **Locate the GF by opening breakers until fault goes away**
  - **Second GF potentially damaging**
  - **GF indication required in NEC2005**
- Still plenty of such systems in operation, but no longer common for new installations

Solidly Grounded

- Neutral directly connected to ground through low-impedance path
- Mandated in many cases by NEC 250.20
- Pros:
  - Effective in limiting ph-ground overvoltages
  - Only scheme that can serve L-N loads
  - Ground faults quickly isolated w/proper protection
- Cons:
  - Potential for high-energy ground faults
    - Damage? Downtime?
  - Many systems have poorly coordinated GF protection systems (one level of GF protection)

Impedance Grounded

- Resistor or reactor inserted between neutral and ground
  - Reactance: generator applications
  - Resistance: transformer-derived systems
- High-resistance (HRG) or Low-resistance (LRG)
  - HRG: limit GF current to 10A or less (480V)
  - LRG: limit GF current to 200-1200A (5-15kV)
- Since ground fault current is limited, the energy released during a fault is greatly reduced

Benefits of LRG/HRG System

- Improved safety
  - GF current may be severely limited
  - Arcing GF less energetic
  - Less likely to escalate to multi-phase events
- Benefit somewhat hard to quantify
  - Grounding impedance doesn't do anything to limit available fault current for a three-phase fault
  - AF Calculations: based on this worst-case exposure
  - The idea is that HRG would make such faults less likely to occur
- Other benefits
  - Increased uptime (particularly HRG)
  - Decreased equipment damage

Disadvantages of LRG/HRG

- Can't serve L-N loads
  - Requires isolation transformer
- Must be maintained and operated by qualified personnel
  - Trained to understand and operate HRG system
  - Having qualified employees is a problem?
- 2nd ground fault still potentially damaging (LV only)
  - As for UG system—2LG fault
  - Requires diligence in locating & clearing GF
- Additional cost to install/retrofit system

Arc Flash Mitigation Solutions and Strategies

- Impedance grounding
- Device coordination & Arc Flash
- High-speed fault making
  - **Arc Terminator Construction**
- Contain or redirect Arcing Energy
  - **Arc-Resistant Construction**
- Remote operation/inspection of equipment
- Operational Considerations

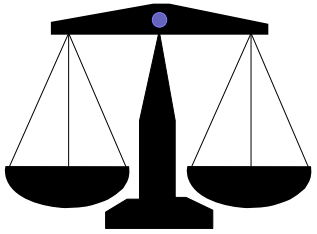
Protective Coordination – "Old Days" (Pre-2002)

•Minimize Equipment Damage

Safety First
Economy Considered

Adequate Withstand Ratings
Proper Device Settings

•Maximize Service Continuity



Source: IEEE Buff Book

Protective Coordination - 2005

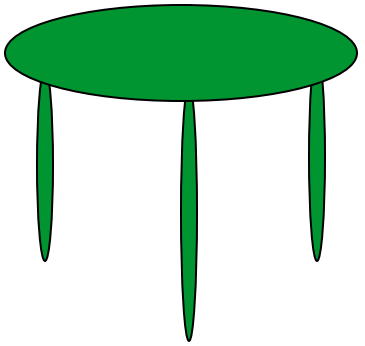
•Minimize Equipment Damage

•Minimize Incident Energy

•Maximize Service Continuity

Economy Considered

Adequate Withstand Ratings
Proper Device Settings
Worker Safety Program

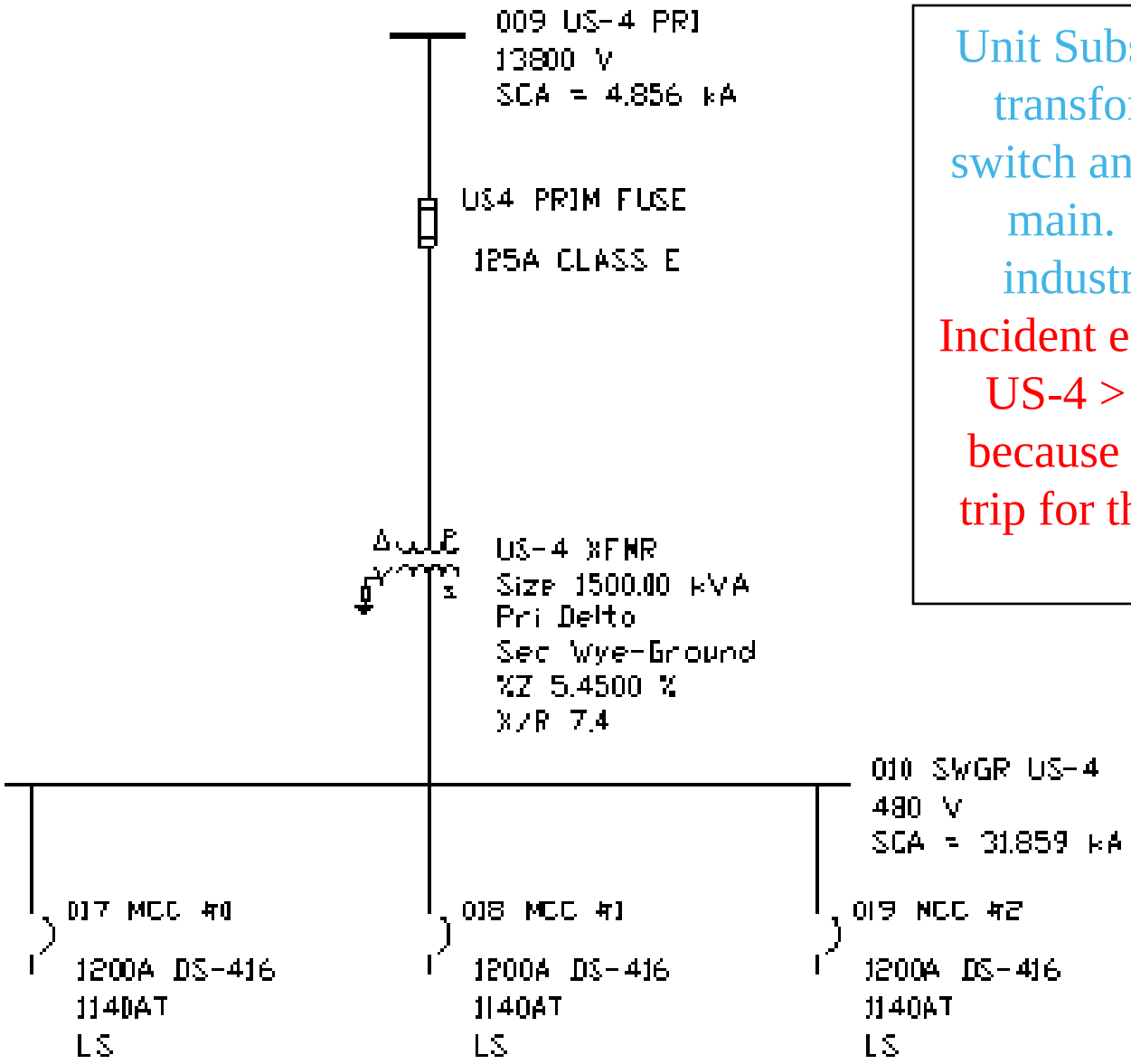


Arc Flash Mitigation Solutions and Strategies

- Impedance grounding
- Device coordination & Arc Flash
- Equipment Design Considerations
- High-speed fault making
  - **Arc Terminator Construction**
- Contain or redirect Arcing Energy
  - **Arc-Resistant Construction**
- Remote operation/inspection of equipment
- Operational Considerations

Equipment Design Considerations

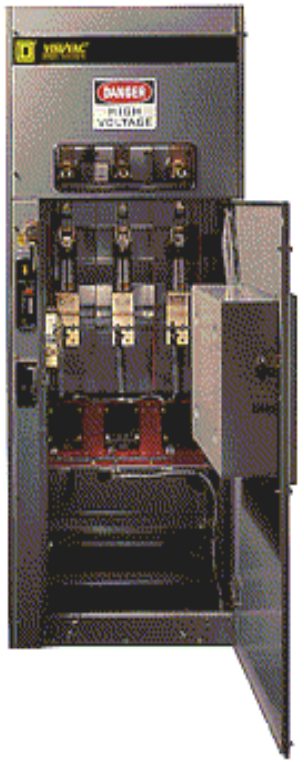
- Service-entrance equipment w/o single, remote, main: almost always has incident energy > 40 cal/cm^2
- Energy reduction in equipment design assumes two things:
  - **The fault on the main bus is actually cleared by the main breaker**
  - **The worker is not exposed to the line side of the main**
- Switchboard Design Considerations
  - Add main OCPD
  - Add barriers between main and feeder section



Unit Substation w/fused transformer primary switch and no secondary main. Common in industrial facilities.

Incident energy at SWGR US-4 > 1000 cal/cm^2 because fuse is slow to trip for the 480V arcing fault.

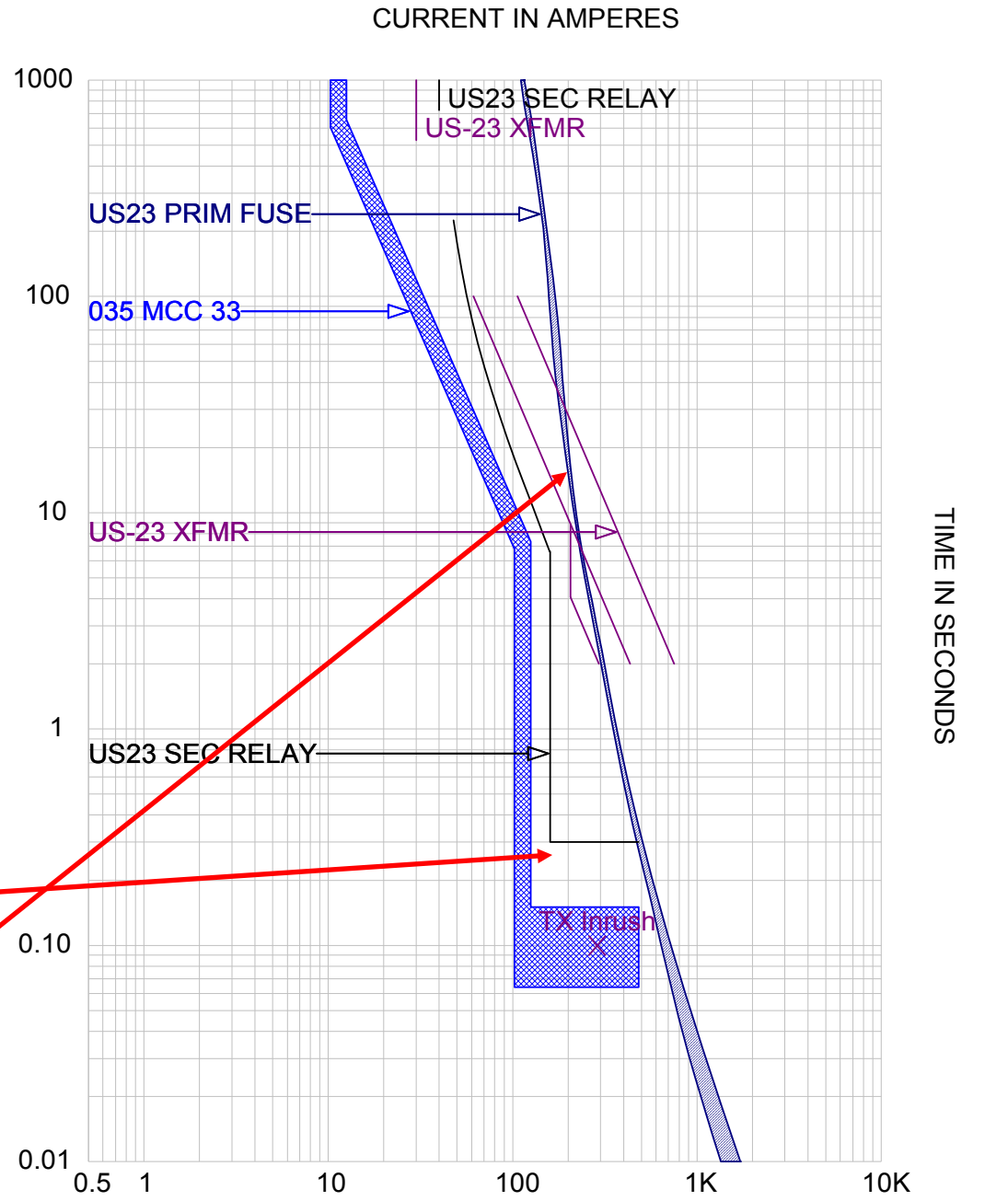
Solution – Virtual Main



- Add CTs & relaying on the secondary side of the transformer and use this to trip out an OCPD at the MV level for a fault on the LV side of the substation

- What to trip?
  - Replace fused switch w/circuit-interrupter switchgear
  - Upstream MV feeder breaker
    - If MV feeder serves several transformers, this is not the ideal solution
    - Another example of tradeoff between protection & selectivity

Add “US23 SEC RELAY” to trip transformer primary device. Reduces AFIE at unit substation from 6600 cal/cm^2 (!) to 22 *cal/cm^2*.



Trip here (0.3 sec),

Not here (??? sec)

! US-23 LOW AF.tcc Ref. Voltage: 480 Current Scale x10^2 Substation

Arc Flash Mitigation Solutions and Strategies

- Impedance grounding
- Device coordination & Arc Flash
- High-speed fault making
  - **Arc Terminator Construction**
- Contain or redirect Arcing Energy
  - **Arc-Resistant Construction**
- Remote operation/inspection of equipment
- Operational Considerations

High-speed Fault Making

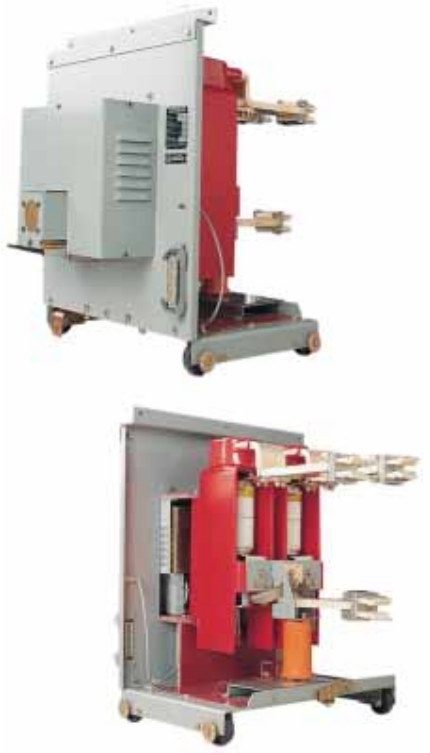
Up until now, when talking about clearing an arcing fault from the system, we've been talking about interrupting it through operation of a protective device

This is not the *only* way to clear an arcing fault...

MV system: we can extinguish the arc more quickly than we can interrupt the circuit

Fault-Making Device

- Three-phase switch installed in the MV switchgear
- When an arcing fault is detected, the switch closes to produce a three-phase bolted fault
- This extinguishes the arc and converts the fault to a bolted fault
- Can happen in ¼ cycle or less—little heat released, little damage done
- Can offer an additional degree of protection to personnel working in close proximity to the medium voltage switchgear, as well as minimize damage to the switchgear itself.



Arc Terminator MV Switchgear

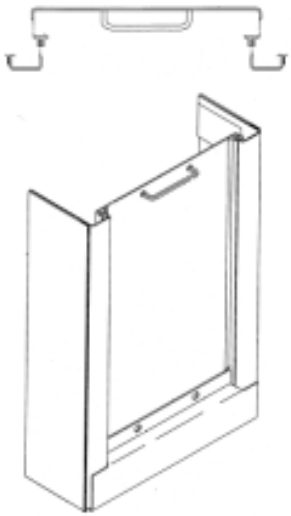
- "Outside-the-box" solution
  - Who in their right mind would create a bolted fault on purpose?
- Not creating a fault—just converting it from a very harmful type to a not-as-harmful type
  - Of course, equipment should be rated to withstand and interrupt bolted fault current
  - Remember Arcing FC ~ 95% of Bolted FC at medium-voltage
- Control system must be designed well—can't afford for this system to be fooled!
  - Light + High Current = Arcing Fault
- Can be installed in new or existing switchgear
  - operation will limit
  - arcing duration and any buildup of high pressure in the switchgear

Arc Flash Mitigation Solutions and Strategies

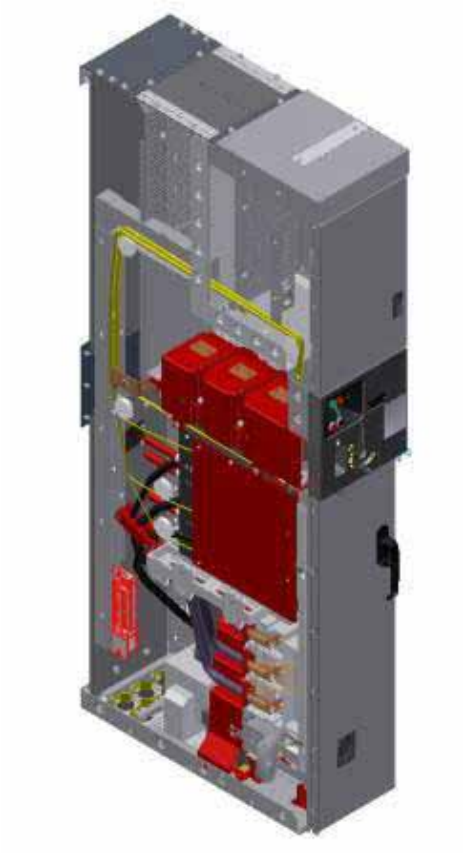
- Impedance grounding
- Device coordination & Arc Flash
- High-speed fault making
- Contain or redirect Arcing Energy
  - **Arc-Resistant Construction**
- Remote operation/inspection of equipment
- Operational Considerations

Arc-Resistant Switchgear

Top View



Rear View
Bolted Rear Panels



MV Switchgear that is able to resist the effects of an internal arcing fault

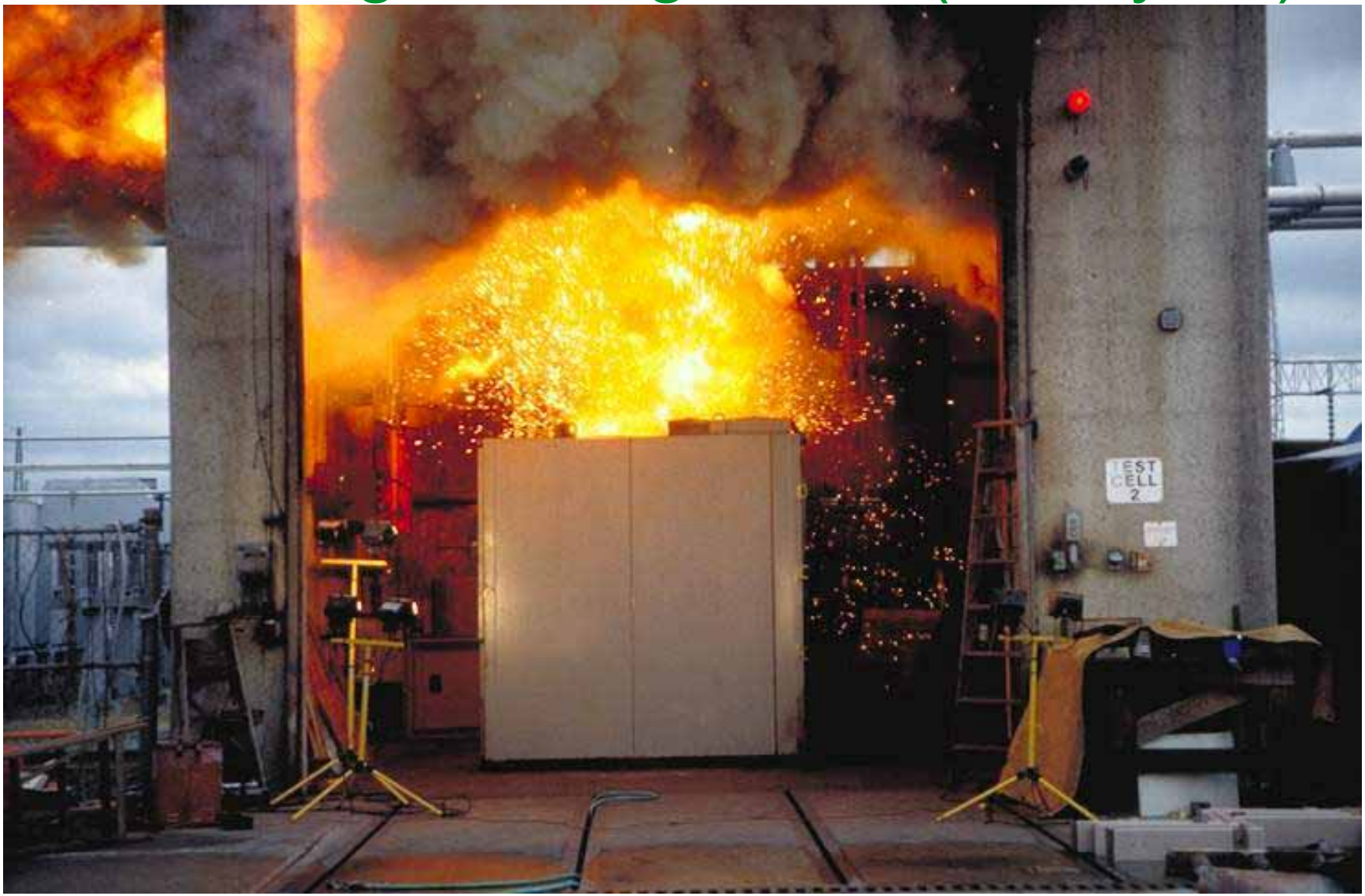
Contains and re-directs the hazard rather than reducing it (energy level unchanged)

May provide significant protection against arc by-products

What Makes it Arc-Resistant?

- Standard switchgear: designed to withstand the effects of a bolted fault
- Arcing faults: heat, pressure, etc.
- Strengthened enclosure
  - Withstand pressure effects of arc
    - Pressure wave, expanding gases
    - Pressures sufficient to shear bolts
  - Contain damage
- Vent by-products outside the gear
  - Pressure-relief vents on top
  - May require room design considerations
    - *"In close proximity" specifically excludes working in, on, above, or below the A-R switchgear (for example, in a cable vault).*

A-R Swgr Testing Photo (BC Hydro)



Arc Flash Mitigation Solutions and Strategies

- Impedance grounding
- Device coordination & Arc Flash
- High-speed fault making
- Contain or redirect Arcing Energy
  - Arc-Resistant Construction
- Remote operation/inspection of equipment
- Operational Considerations

Remote Racking Systems

- Distance from arc source ("working distance") is a major factor determining the level of arc-flash hazard
  - Incident energy drops off roughly as distance squared—double the distance, ¼ the energy
- Solutions that allow greater separation between worker and energy source provide a significant degree of protection
- Example: remote racking of breakers
  - Move worker outside the flash protection boundary

Thermograhpic Scanning

- Inherently hazardous action—requires opening of panel/enclosure
- Using telephoto lens doesn't protect those who have to remove equipment covers
- Installation of IR windows in equipment covers allows scanning w/o opening the gear

Arc Flash Mitigation Solutions and Strategies

- Impedance grounding
- Device coordination & Arc Flash
- High-speed fault making
- Contain or redirect Arcing Energy
  - Arc-Resistant Construction
  - Other equipment design considerations
- Operational Considerations

Temporary Setting Changes

- There is often a tradeoff between protection and selective coordination
- If settings of breakers or relays can be temporarily modified (turn INST on, turn INST down to lower level, etc.), they may be able to provide better protection
  - **Coordination temporarily compromised**
  - **Only when someone present & doing work**
- Turn settings back up when work complete
- Problems:
  - **Requires analysis to determine appropriate “temporary” settings**
  - **Not every OCPD allows temporary changes**
  - **What if workers forget to return settings to “as-found” levels?**

Summary

- Arc Flash is a significant electrical safety concern
- Industry standards are in place to address the issue
  - Require selection and use of PPE
  - But PPE is to be a last line of defense!
- System design considerations can reduce the potential exposure to arc flash
  - #1 goal: no energized work
  - #2 goal: if work must be done energized, at least let it be done on a system that is properly designed, maintained and operated.