



ARC FLASH STUDIES AND SOLUTIONS

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Presenter:

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PRESENTATION OVERVIEW

- What is Arc Flash?
- Review of Standards: Enforcement & Compliance
- Arc Flash Study Complete – What Now?
- Practical Methods for Reducing Arc Flash Hazards

WHAT IS ARC FLASH?

NFPA 70E–2012 Article 100. Arc Flash Hazard.

- A dangerous condition associated with the possible release of energy caused by an electric arc.
 - **Informational Note** No. 1: An arc flash hazard may exist when energized electrical conductors or circuit parts are exposed or when they are within equipment in a guarded or enclosed condition, provided a person is interacting with the equipment in such a manner that could cause an electric arc. Under normal operating conditions, enclosed energized equipment that has been properly installed and maintained is not likely to pose an arc flash hazard.
 - **Informational Note** No. 2: See Table 130.7(C)(15)(a) and Table 130.7(C)(15)(b) for examples of activities that could pose an arc flash hazard.

What is “Arc Flash”?

Arc Flash Happens throughout the Power System:

Switchgear



MCC



Panelboard



Plug-in Bus Duct



Standards Covering Arc Flash

- National Fire Protection Agency (NFPA)
 - NFPA 70-2011 *National Electric Code (NEC)*
 - NFPA 70E-2012 *Standard for Electrical Safety in the Workplace*
- Occupational Safety and Health Administration (OSHA)
 - OSHA 29 CFR Part 1910
- Institute of Electrical and Electronics Engineers (IEEE)
 - C2-2007 *National Electric Safety Code (NESC)*
 - 1584-2002 *Guide for Performing Arc Flash Hazard Calculations*

Review of Standards: Enforcement and Compliance

Enforcement and Compliance

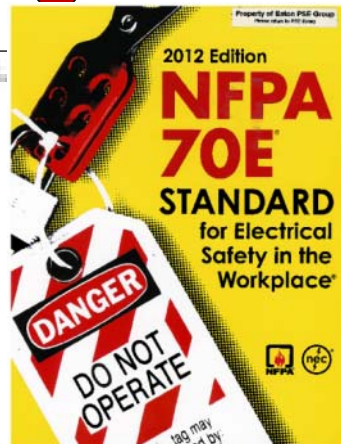
U.S. Industrial/Commercial



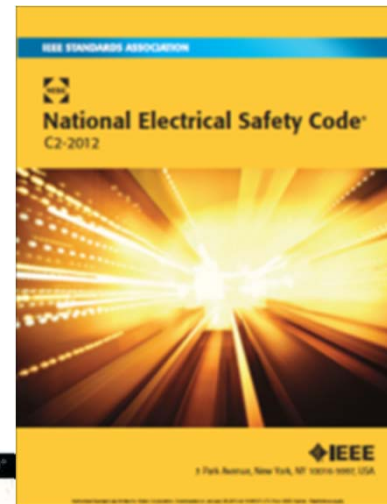
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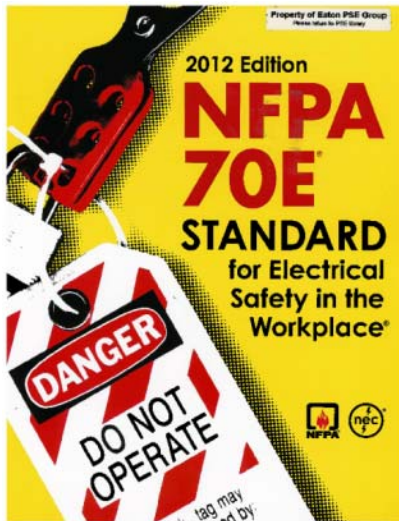


Canada



Enforcement and Compliance: NFPA

- **130.5 Arc Flash Hazard Analysis.** An arc flash hazard analysis shall determine the arc **flash boundary**, the **incident energy at the working distance**, and the personal protective equipment that people within the arc **flash boundary** shall use.
 - **Exception:** *The requirements of 130.7(C)(15) and 130.7(C)(16) shall be permitted to be used in lieu of determining the incident energy at the working distance.*
 - **Informational Note No. 2:** *Both larger and smaller available short-circuit currents could result in higher available arc flash energies*
 - **Informational Note No. 3:** *The occurrence of an arcing fault inside an enclosure produces a variety of physical phenomena very different from a bolted fault.....Equipment and design practices are available to minimize the energy levels.....*



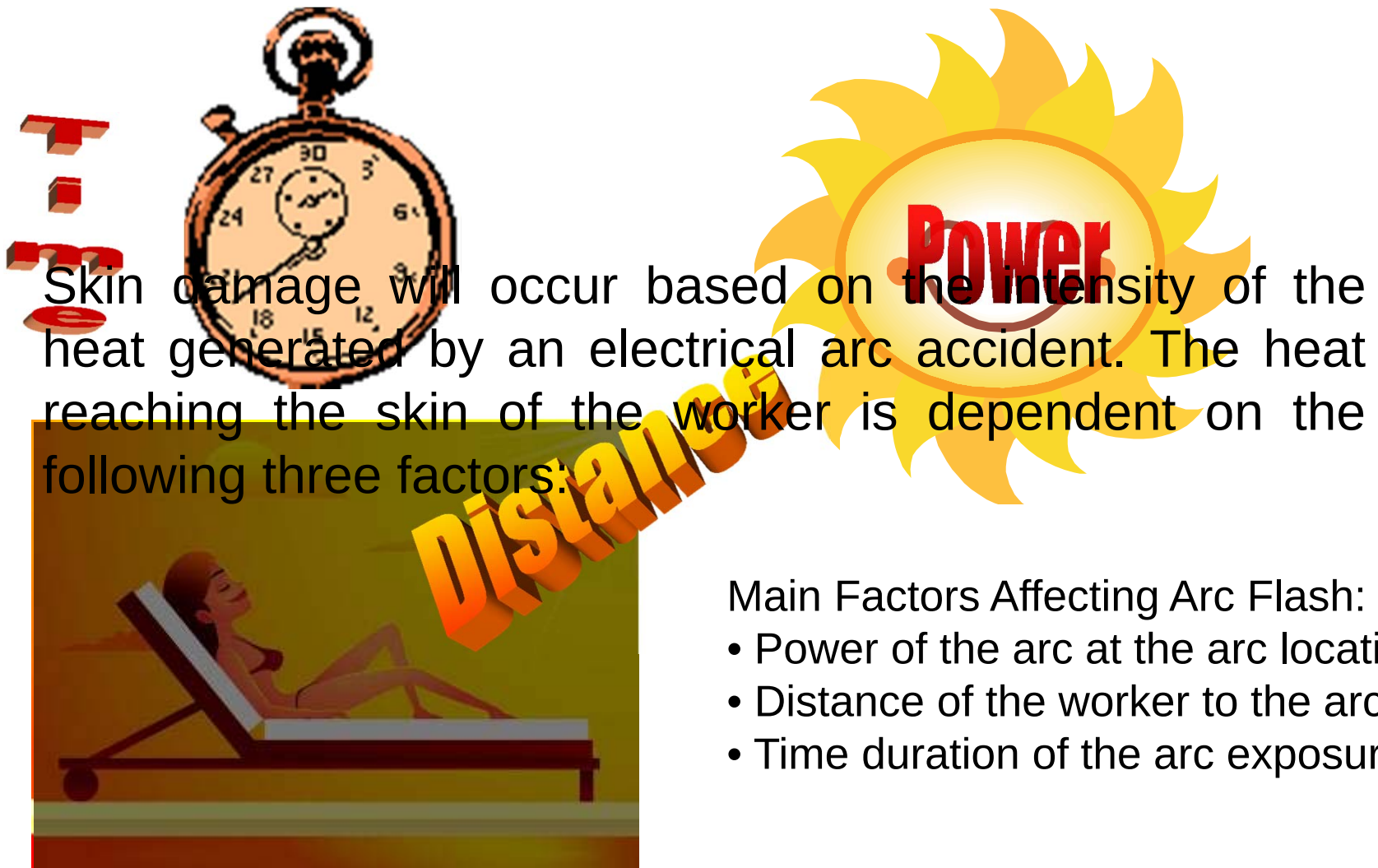
Enforced by OSHA

Enforcement and Compliance: NFPA

- **130.5(C) 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 are likely to require examination, adjustment, servicing, or maintenance while energized, shall be field marked with a label containing all the following information:
 - (1) At least one of the following:
 - a. Available incident energy and the corresponding working distance
 - b. Minimum arc rating of clothing
 - c. Required level of PPE
 - d. Highest Hazard/Risk Category (HRC) for the equipment
 - (2) Nominal system voltage
 - (3) Arc flash boundary

Arc Flash Study Analysis

Three Main Factors Affecting Incident Energy and Arc Flash



Time

Power

Distance

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:

- Power of the arc at the arc location
- Distance of the worker to the arc
- Time duration of the arc exposure

IEEE Arc Flash Analysis Steps

- Step 1: Collect existing oneline diagrams and power system data
- Step 2: Determine the power system's modes of operation
- Step 3: Determine the bolted fault currents
- Step 4: Determine the arc fault currents
- Step 5: From the protective device characteristics, find the arcing duration
- Step 6: Record system voltages and equipment classes
- Step 7: Determine working distances
- Step 8: Determine incident energy for each work location in the study
- Step 9: Determine the flash-protection boundary for each work location in the study

Additional Arc Flash Analysis Steps

- Step 10: Examine all “unacceptable” locations
- Step 11: Determine methods to reduce the incident energy at these locations
- Step 12: Implement arc flash reduction solutions
- Step 13: Re-run the arc flash analysis taking the solutions into account
- Step 14: Print and install arc flash hazard warning labels
- Step 15: Train all workers who will work on or near energized equipment

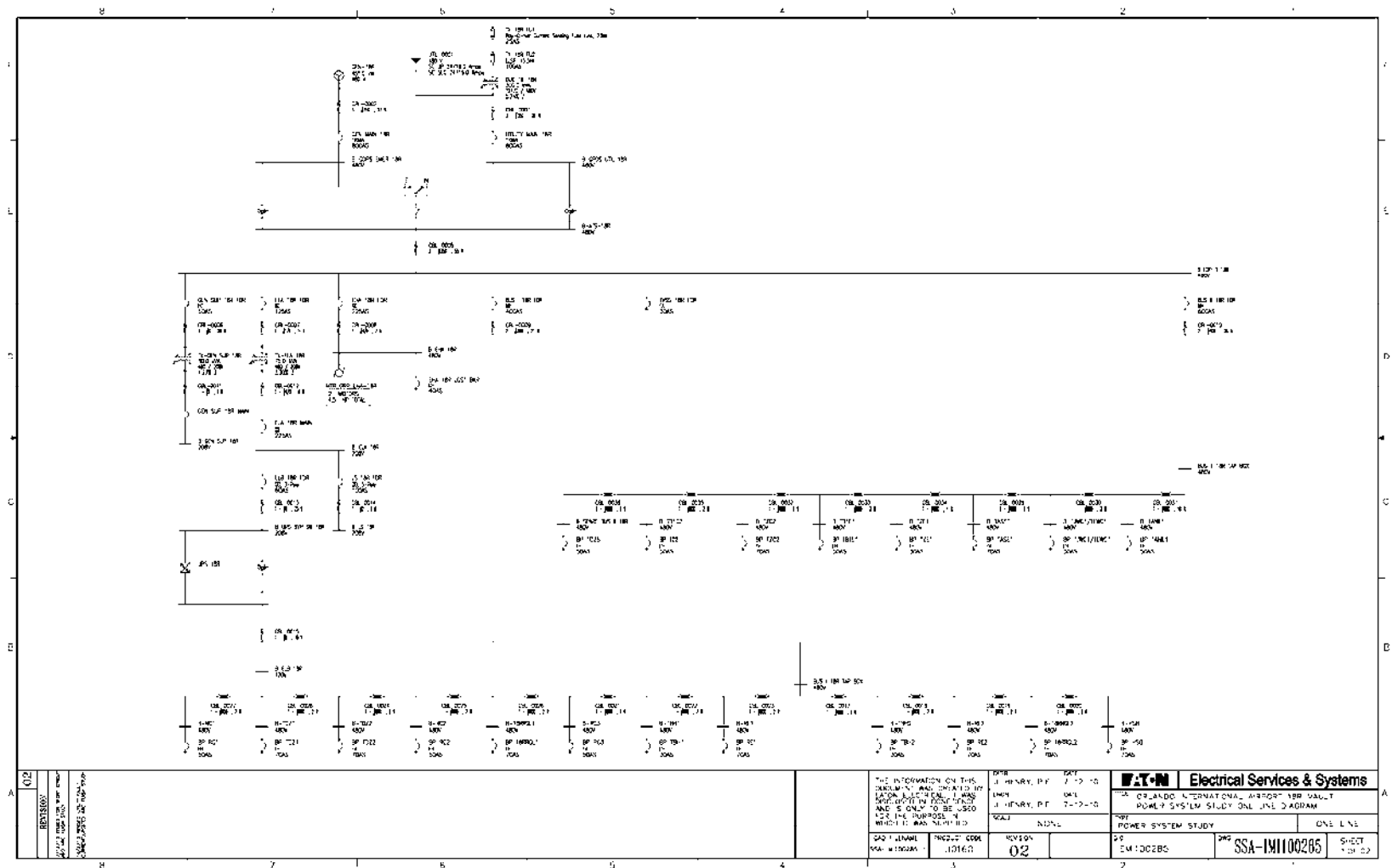
Arc Flash Study Complete – What Now?

- You get Arc Flash Analysis That Looks Like This!

Bus Name	Device Name	Bus kV	Bus Bolted Fault kA	Device Bolted Fault kA	Device Arcing Fault kA	Trip Time sec.	Bkr. Opening sec.	GND	Equip	Gap mm	AF Boundary in.	Working Distance in.	Incident Energy cal/cm ²
BUS-50CP1	R-CP1	0.440	48.23	38.65	17.01	0.725	0.05	No	SWG	32	260	24	40.0
BUS-50CP2	R-CP2	0.440	47.7	38.92	17.16	0.753	0.05	No	SWG	32	267	24	41.6
BUS-50FD1	R-FD1	0.440	69.57	63.15	25.92	1.95	0.05	No	SWG	32	652	24	154.7
BUS-50FD2	R-FD2	0.440	73.9	62.14	25.22	1.95	0.05	No	SWG	32	648	24	153.5
BUS-50FD3	R-FD3	0.440	74.89	63.28	25.62	1.95	0.05	No	SWG	32	654	24	155.5
BUS-50FD4	R-FD4	0.440	69.33	62.9	25.84	1.95	0.05	No	SWG	32	651	24	154.5
BUS-50ID1	R-ID1	0.440	95.76	62.58	24.18	1.95	0.05	No	SWG	32	656	24	156.3
BUS-50ID2	R-ID2	0.440	95.19	60.51	23.41	1.95	0.05	No	SWG	32	645	24	152.3
BUS-50LP1	50LP1-MAIN	0.208	47.29	41.62	10.59	2	0	No	SWG	32	346	24	60.8
BUS-50LP1 (Line Side)	R-LP1	0.208	47.29	41.62	10.59	1.95	0.05	No	SWG	32	346	24	60.8
BUS-50LP2	50LP2-MAIN	0.208	51.06	41.6	10.33	2	0	No	SWG	32	346	24	61.0
BUS-50LP2 (Line Side)	R-LP2	0.208	51.06	41.6	10.33	1.95	0.05	No	SWG	32	346	24	61.0
BUS-50M1	R-M1	0.440	42.87	38.91	17.51	0.742	0.05	No	SWG	32	263	24	40.5
BUS-50M2	R-M2	0.440	42.62	38.65	17.41	0.745	0.05	No	SWG	32	262	24	40.5
BUS-50M3	R-M3	0.440	43.13	38.7	17.4	0.746	0.05	No	SWG	32	263	24	40.6
BUS-50M4	R-M4	0.440	44.78	39.35	17.56	0.741	0.05	No	SWG	32	265	24	41.0
BUS-5EX1	R-5EX1	0.440	79.6	56.53	22.62	1.95	0.05	No	SWG	32	616	24	142.4
BUS-5EX2	R-5EX2	0.440	63.37	63.37	26.48	1.95	0.05	No	SWG	32	657	24	156.6

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Innovative Techniques for Mitigating Arc Flash Exposure

Things to Consider for Arc Flash Mitigation

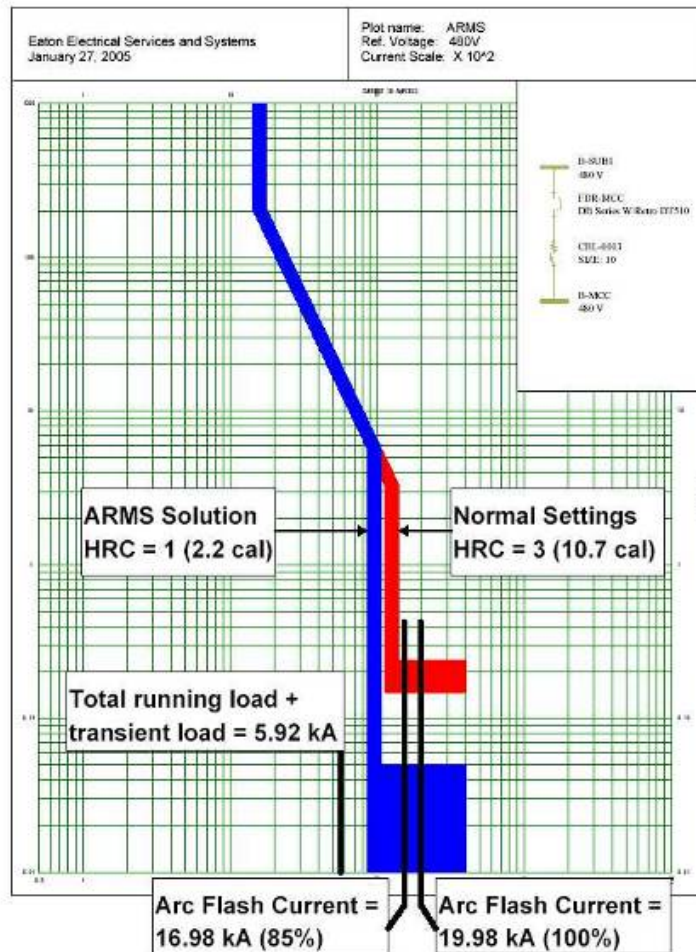
- **Visit Customer Site**
- **Recommend Arc Flash Solutions Study!**
- Location, Location, Location – will determine your solution
 - Physical Location – can equipment be brought in easily?
 - Environment of Location - tight equip fit, dirty, air quality, etc?
 - Is there asbestos at Location, watch for in older plants?
 - Extra Space at Location – to add on main breaker cubicle?
 - Utility own the incoming transformer?
 - Most of the time, the AF Incident Energy is calculated to be > 40 cal/cm² for the secondary side of substation transformers ≥ 750 kVA
- Condition of Switchgear
 - Does it physically need replaced?
 - Physically, is it worth doing retrofits or retrofills?
- Maintenance of Equipment
 - How often is equipment worked on energized (daily, weekly, etc)?
 - How often is equipment tested?

Eaton Arc Flash Solutions 2012

- Engineered Solutions:

EATON ARC FLASH SOLUTIONS QUICK SELECT APPLICATIONS GUIDE			
Arc Flash Solutions	Installation	Where Applied	AF Lbl Change
Adjust Breaker Settings	Existing	MV/LV Breaker Relay/Trip Unit	Possible
Arc Flash Limiter (AFL) System	Retrofit	LV Substations, subs with no main sec. bkr.	Yes
Arc Flash Reduction Maintenance Switch Retrofit Kits	Retrofit	LV SWGR Power Breakers	Yes
MV A.R.M.S. Using EDR-3000/4000/5000	New EQPT/Retrofit	MV SWGR	Yes
Fused Switch to Breaker Retro Fills	Retrofill	LV SWGR Mains	Yes
Pringle Switch to Magnum Breaker Retrofit	Retrofit	LV SWGR Power Breakers	Yes
Low Voltage Air Replacement Breakers (LVAR's)	Retrofill	LV SWGR Power Breakers	Yes
Bus Differential Schemes	Existing/New EQPT	MV/LV SWGR	Yes ⁽¹⁾
Barriers for Line/Load - Side Arc Flash Calculations	Retrofit	Panelboards & Switchboards	Yes
NOTES:			
(1) AF mitigation may only apply to certain equipment sections or certain maintenance tasks			

Adjust Breaker Settings



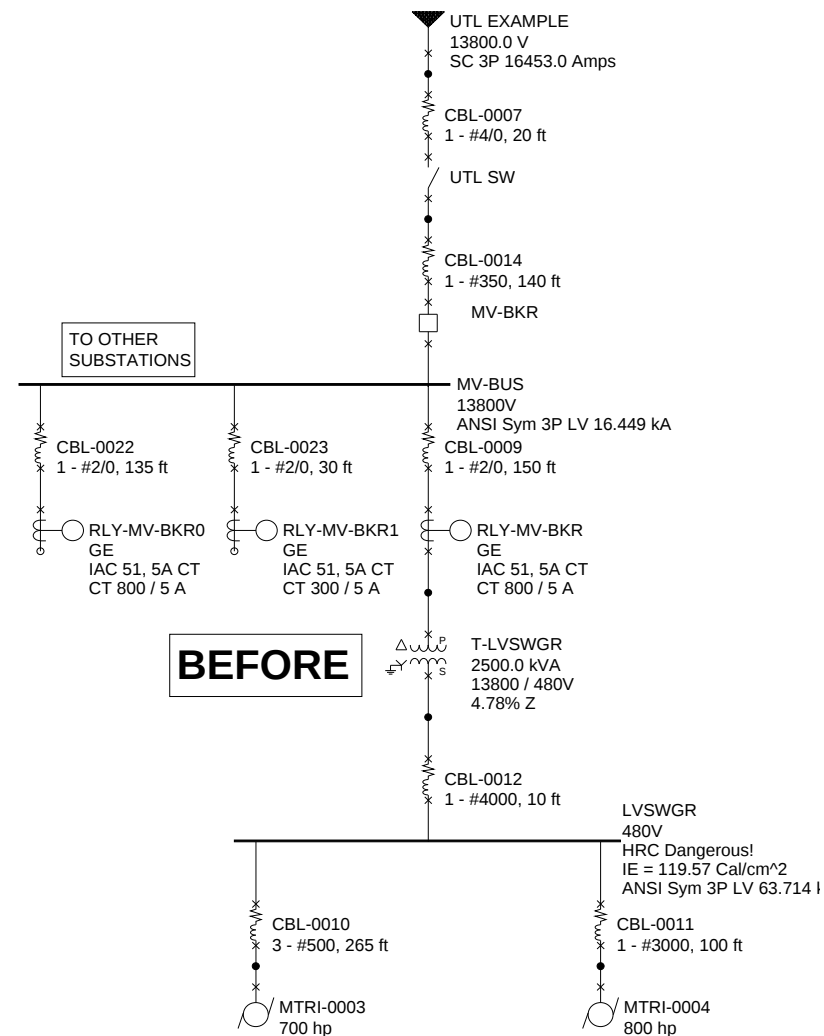
Eaton Arc Flash Solutions 2012

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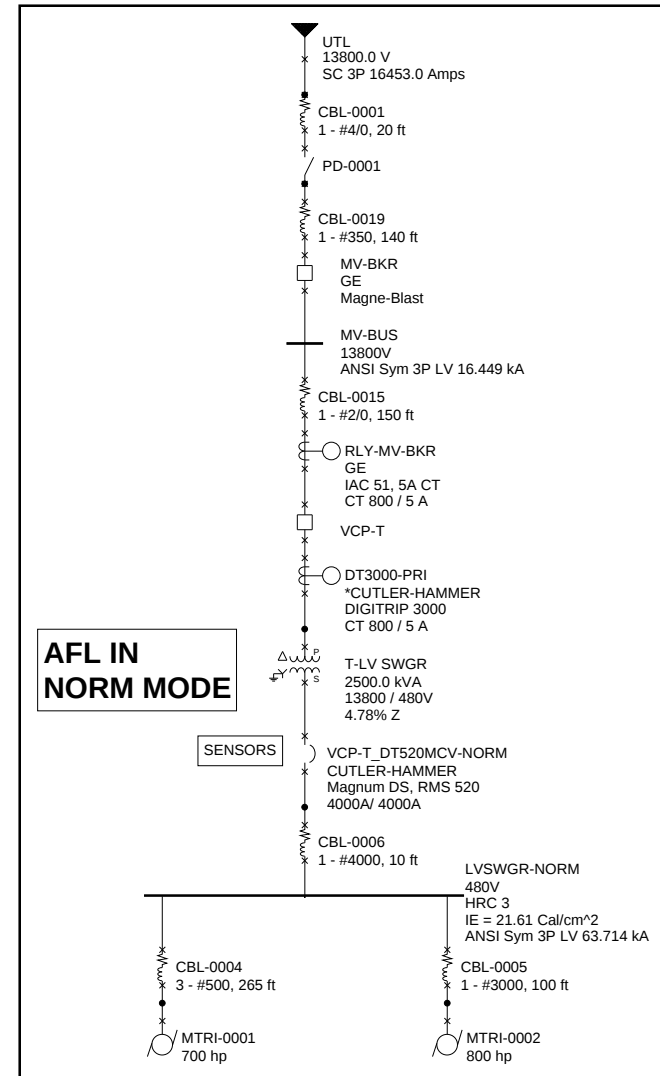
Arc Flash Study Complete – What Now?

- Example 1: Power Generation Plant:
- Existing Power System - 1 MV GE Magne-Blast feeding 3 low voltage substations – each w / separate protective relays
 - Substations are all similar
 - Incident Energy > 40 cal/cm² @ the Low Voltage Switchgear (common to all subs)
 - Notice 700hp & 800hp motors – must consider for arc flash mitigation (false trips could occur when motor starts w / ARMS engaged)
- Arc Flash Solution for Low Voltage Switchgear (LV SWGR)?



Arc Flash Study Complete – What Now?

- **Recommend Arc Flash Limiter (AFL)**
 - Uses the VCP-T medium voltage vacuum breaker, which provides primary short circuit protection in place of fuses
 - Transformer Primary Protection – Protective Relay & ct's
 - Transformer Secondary Protection – Integral Trip Unit, with Arc Flash Reduction Maintenance Switch (ARMS)
 - AFL use's special Low Voltage sensors with 1A secondary (not ct's), which the integral trip unit uses to sense the low voltage side of transformer for much faster tripping



Arc Flash Study Complete – What Now?

- **Arc Flash Table – Low Voltage Switchgear Incident Energy comparison:**
 - 1.) LVSWGR: Existing relay protection (NO AFL installed)
 - 2.) LVSWGR-NORM: Normal AFL mode protection
 - 3.) LVSWGR-VCP-T_ARMS: ARMS Engaged AFL protection
 - 4.) LVSWGR-VCP-T_RLY: Custom Arc Flash Mitigator (CAM) secondary protection using protective relay & standard ct's

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 (sec.)	GND	Equip Type	Gap (mm)	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm ²)
LVSWGR	RLY-MV-BKR	0.48	65.4	55.05	25.33	1.95	0.05	Yes	SWG	32	547.20	24	119.57
LVSWGR-NORM	VCP-T_DT520MCV-NORM	0.48	65.4	55.05	25.33	0.3	0	Yes	SWG	32	154.95	24	18.64
LVSWGR-VCP-T_ARMS	VCP-T_DT520MCV-ARMS	0.48	65.4	55.05	25.33	0.04	0	Yes	SWG	32	42.50	24	2.77
LVSWGR-VCP-T_RLY	VCP-T_RELAY	0.48	65.4	55.05	25.33	0.05	0.05	Yes	SWG	32	77.88	24	6.77

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- Arc Flash Solution Products:

EATON ARC FLASH SOLUTIONS QUICK SELECT APPLICATIONS GUIDE			
Arc Flash Solutions	Installation	Where Applied	AF Lbl Change
MV and LV Zone Selective Interlocking	Existing/New EQPT	PNLBD's, SWBD's, SWGR	Yes ⁽¹⁾
MV VCP-T Breakers with Integral ARMS	Existing/New EQPT	MV SWGR	Yes
Magnum LV Swgr with Integral ARMS	Existing/New EQPT	New Magnum LV SWGR (ARMS built-in)	Yes
Low Voltage Molded Case Circuit Breakers with ARMS	New EQPT/Retrofit	New PNLBD's & SWBDS, breaker replacements	
Net Work Protector ARMS	Existing/New EQPT	LV Utility Spot Networks	Yes
MV/LV Remote Pwr Racking/RPR2/Factry	Existing/New EQPT	Existing MV/LV SWGR Installations	No
FlashGard MCCs with Remote Racking	Existing/New EQPT	New MCC Installation	No
FlashGard MCC Bucket Retrofits	Existing/New EQPT	Existing Eaton and Competitor MCC's	No
Arc Resistant MV Motor Starters (Ampgard)	New EQPT	New MV SWGR Installation	No
MV Arc Resistant Swgr	New EQPT	New MV SWGR Installation	No
LV Arc Resistant Swgr	New EQPT	New LV SWGR Installation	No
AF Tested Current-Limiting MCCBs	New EQPT/Retrofit	New PNLBD's & SWBDS, breaker replacements	Possible
Infra-Red Windows	New EQPT/Retrofit	Transformers/SWGR	No
Infra-Red Sensors in Hi AF Areas	New EQPT/Retrofit	Transformers/SWGR	No
EZ™ Lighting Panelboards	New EQPT/Retrofit	LV PNLBD's	No
MCCB Remote ARMS Control	New EQPT/Retrofit	LV PNLBD's	No
NOTES:			
(1) AF mitigation may only apply to certain equipment sections or certain maintenance tasks			

Eaton Arc Flash Solutions 2012

- Arc Flash Prevention Solutions:

EATON ARC FLASH SOLUTIONS QUICK SELECT APPLICATIONS GUIDE			
Arc Flash Solutions	Installation	Where Applied	AF Lbl Change
MV/LV High Resistance Grounding Systems	Existing/New	MV/LV Substations/SWGR	No
Remote Monitoring, Control and Diagnostics	Existing/New	MV/LV Substations/SWGR	No
Ampgard Remote Operators	Existing/New	MV Ampgard SWGR	No
GearGard Continuous Monitoring	Existing/New	MV/LV Substations/SWGR	No
Hi (or Low) Impedance Transformers	Existing/New	MV/LV Substations	No
Insulated Bus in Switchgear	New EQPT	New MV/LV SWGR Installation	No
Current Limiting Reactors	Retrofit	MV/LV Substations/SWGR	Possible
Partial Discharge Systems / InsulGard	New EQPT/Retrofit	MV/LV Substations/SWGR	No
Kirk Key Interlock Systems	New EQPT	MV/LV Substations/SWGR	No
MCC Bucket & Safety Switch Viewing Windows	New/Retrofit	MCC's	No
MCCB Remote Operator	New/Retrofit	MCCB's	No
NOTES:			
(1) AF mitigation may only apply to certain equipment sections or certain maintenance tasks			

***Label Equipment, Train People, Wear
PPE***

Practical Methods for Reducing Arc Flash Hazards

Minimize Risk with Good Safety Practices

- De-Energize Equipment versus “Working It Live” unless increased hazards exist or infeasible due to design or operational limitations.
- Switching remotely (if possible)
- Closing and tightening door latches or door bolts before operating a switch.
- Standing to the side and away as much as possible during switching operations.

Train People

- **Arc-Flash Safety** – 4.0 hours, for electricians, technicians or equipment operators whose employers have already declared them to be "qualified" according to OSHA rules
- **Electrical and Arc-Flash Safety** – 8.0 hours, for electricians, technicians and equipment operators who are not "qualified" but who might be exposed to arc-flash hazards
- **Custom Arc Flash Training** – per customer requirements (on site or local), could include performing power system analysis software.

Wear Personal Protective Equipment (PPE)

- Cumbersome
- Hot
- Reduces Mobility
- Increases Fatigue



Label Equipment



- Arc Flash Studies
- Standardized Data Collection Templates
- 87+ Power Systems Engineers
- Labels, Training, Recommendations

 WARNING SHOCK & ARC FLASH HAZARD	
EATON Powering Business Worldwide	
Location: REEFER PWR CTR 4 Label #146 Report #: TQSISE0007429.3 Rev. 0 Issued: AUG-2012	
LINE SIDE of MAIN	24' - 8" ARC FLASH BOUNDARY WARNING! GREATER THAN 40 cal/cm ² CALCULATED INCIDENT ENERGY AT 1' - 6" WORKING DISTANCE. REFER TO STUDY REPORT AND SITE SAFETY PROGRAM FOR ADDITIONAL SAFETY INFORMATION.
	4' - 2" ARC FLASH BOUNDARY 6.4 cal/cm² CALCULATED INCIDENT ENERGY AT 1' - 6" WORKING DISTANCE
LOAD SIDE of MAIN	480 V Shock Hazard Limited Approach Boundary: 3' - 6" Min. Glove Class: 00 Restricted Approach Boundary: 1' - 0" Prohibited Approach Boundary: 0' - 1"

***Reduce Available Fault Current
(Reduce Incident Energy - but not always
the case)***

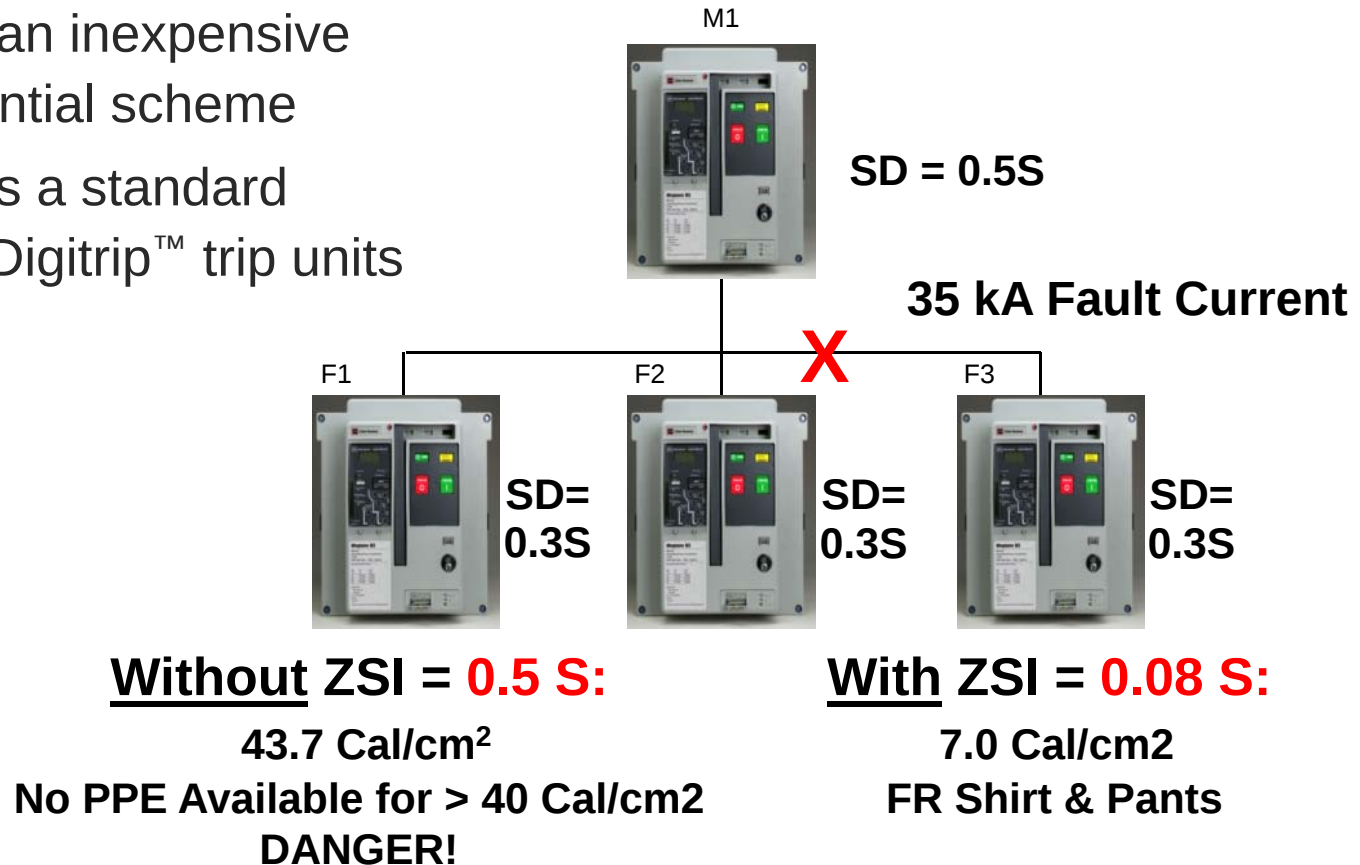
Faster Clearing Time

High Speed Clearing

- Bus Differential (87B)—MV or HV
- Zone Selective Interlocking – a Control approach / Form of 87B – MV and LV
- Arc Flash Reduction Maintenance Switch (ARMS)

Arc Flash Safety Solutions LV Power Breakers — Zone Selective Interlocking (ZSI) for Arc Flash Reduction

- ZSI is like an inexpensive bus differential scheme
- Included as a standard feature in Digitrip™ trip units



Faster Clearing Time

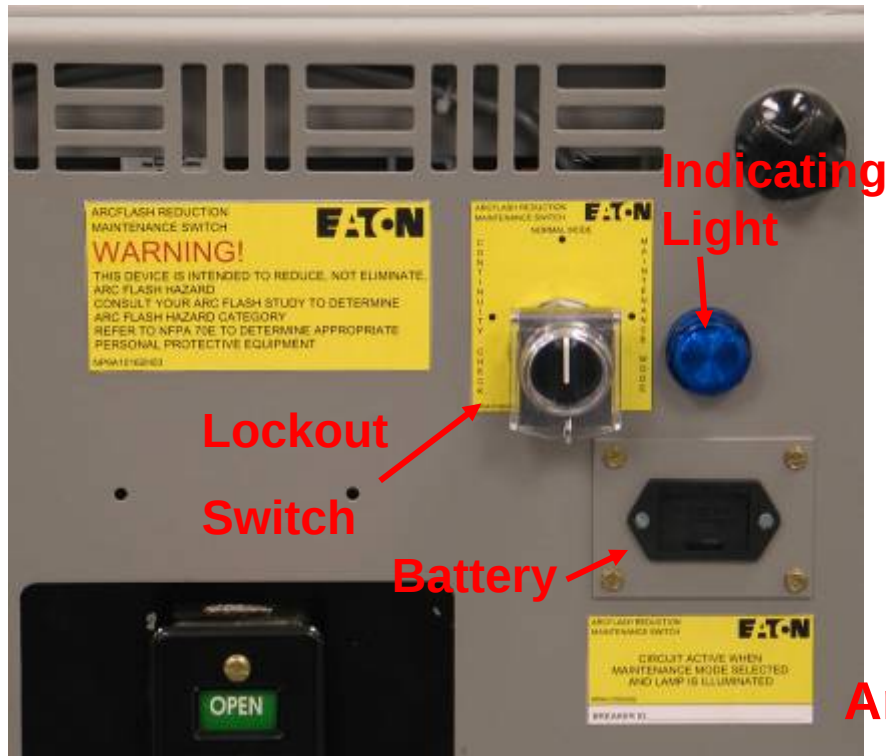
Arcflash Reduction Maintenance System™ – Integral to Trip Unit



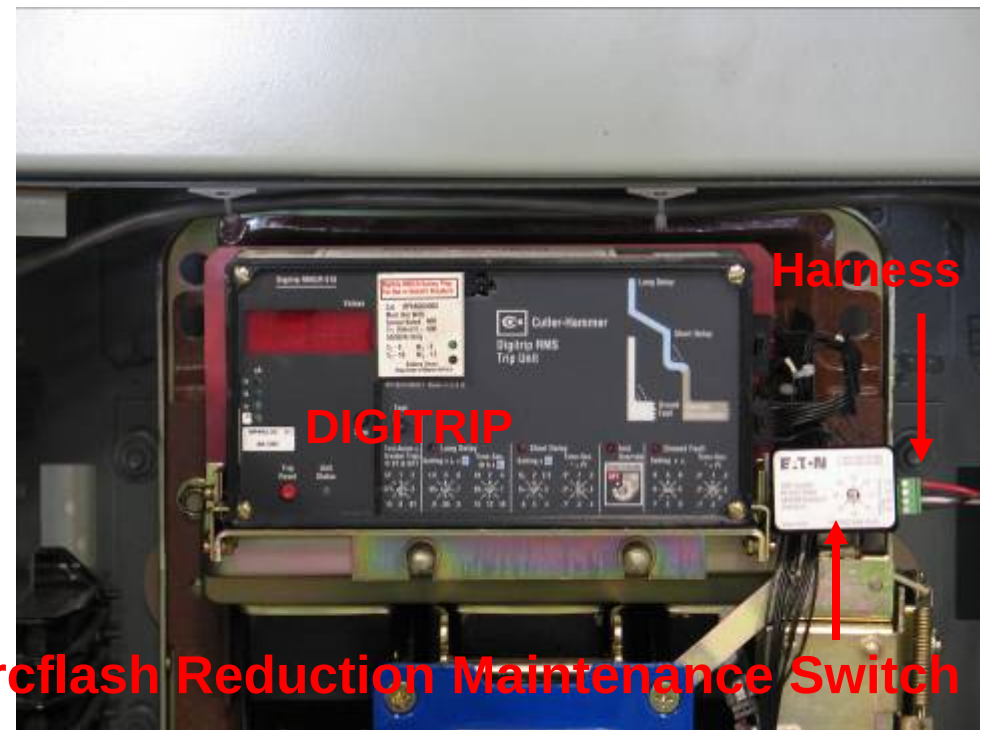
- Has 5 user-selectable levels of protection to choose maximum protection, while avoiding nuisance tripping
- Blue color LED indicating Maintenance mode
- Can be remotely activated through IR communication with PDA
- DT 1150 Available Now

Arcflash Reduction Maintenance Switch™ - Retrofit of LV - PCBs

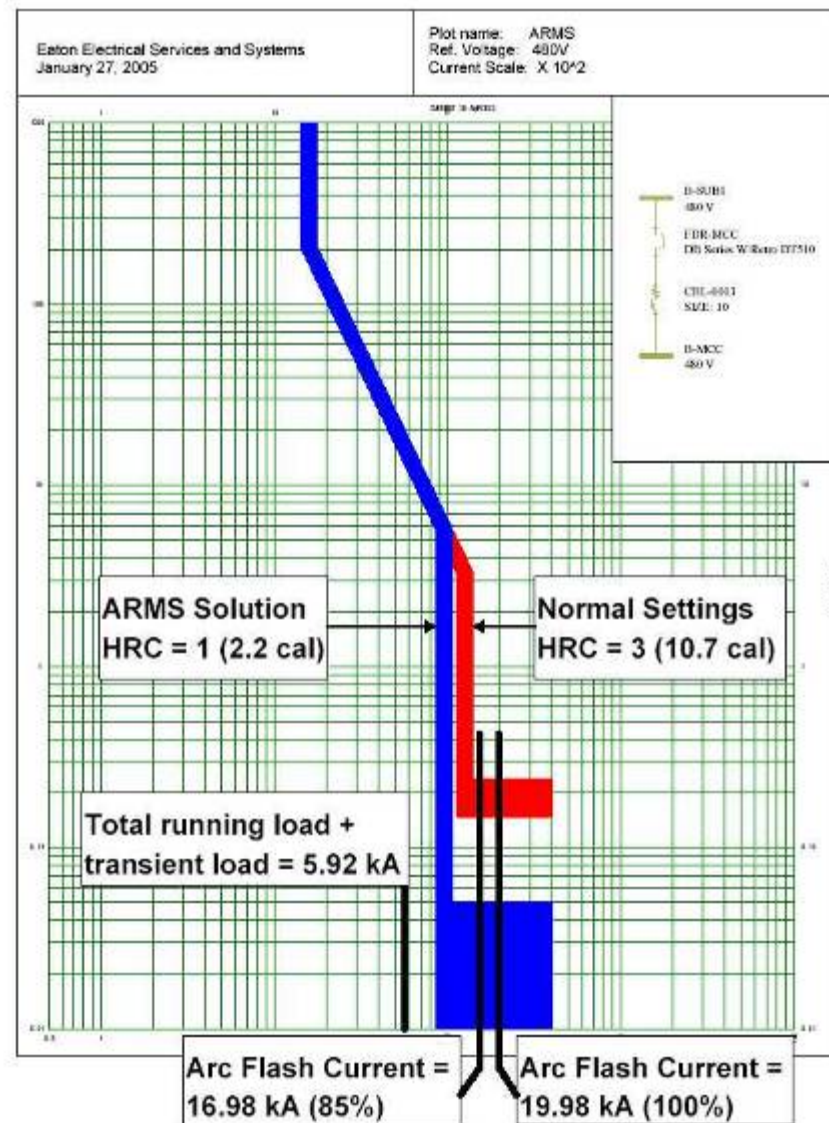
- Door Mounted Components



- Breaker Mounted Components



Example: Arcflash Reduction Maintenance Switch (ARMS) - High Available Fault Current



- High Avail Fault Current
- Digitrip610 & Arcflash Reduction Maintenance Switch
- Normal settings
 - $ie = 10.7 \text{ cal/cm}^2$
- **With Arcflash Reduction Maintenance Switch**
 - $ie = 2.2 \text{ cal/cm}^2$

Arc Flash Solutions; REMOTE ARMS

– New in 2006



Multiple Settings Groups

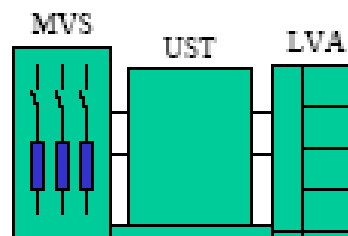
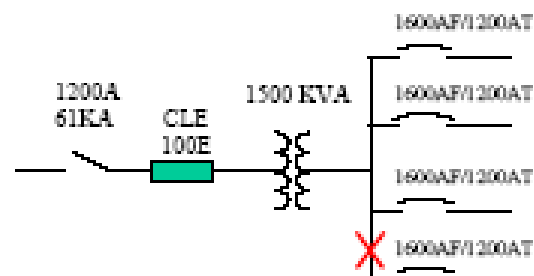
- Similar to LV maintenance switch, only for MV applications
- Used to reduce the trip delay of medium-voltage relays while maintenance is being performed on equipment.
- Requires relay with multiple settings groups capability, such as the Eaton E-Series Relays



Substations Without Main Secondaries AFL Retrofit

MiniVac Primary Switch Retrofit

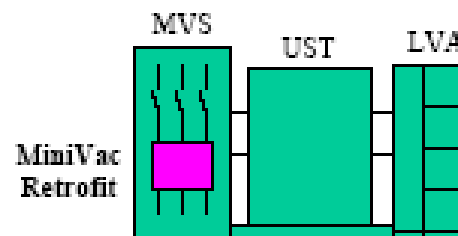
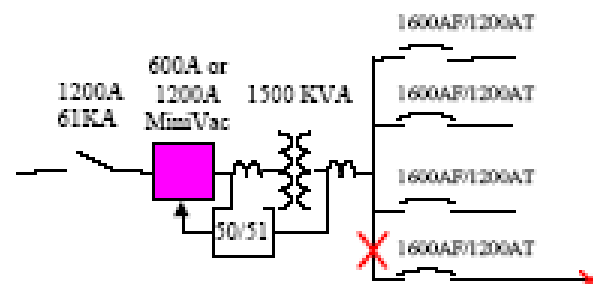
BEFORE



Fault at 480V Switchgear Bus

- 31.8kA Symmetrical Fault current
- 1167" AF Boundary
- 702.4 cal/cm @ 18"
- NFPA70E-2004: Category 4 is highest category @ 40 cal/cm

AFTER



Fault at 480V Switchgear Bus

- 31.8kA Symmetrical Fault current
- 80.9" AF Boundary
- 13.7 cal/cm
- NFPA70E-2004: Category 3

Fault Downstream of LVPCB

- 31.8kA Symmetrical Fault current
- 22.2" AF Boundary
- 1.8 cal/cm @ 18"
- NFPA70E-2004: Category 0

CM52 Network Protector with ARMS



Arcflash Reduction Maintenance System for Network Protectors for Spot Networks

CM52 with ARMS Protection:

- Independent of the MPCV Network Relay
- Derives power via CTs from fault current
- Sub-cycle non-directional RMS detection
- Unlike any conventional Network Protector which provides NO "forward" protection for Collector Bus Network Faults

CM52 Network Protector:

- Dead Front, Draw Out, Lighter Weight Breaker
- Fault Close and Latch Rated Breaker
- Highest NWP Withstand and Thermal Ratings
- Accommodates Internal or External Mount Fuses
- Self-Diagnostics, Reduced Maintenance, only 7 replacement parts
- Test Position with Test Block simplifies full NWP Testing



- SCADA Communication & Control
- Advanced Trip & Close Characteristics
- Pendant or Remote Setpoints
- Auxiliary Inputs, Trip Event Log, Waveforms

Move People Further Away

Arc Flash Safety Solutions

Integrated Racking Motor - Overview

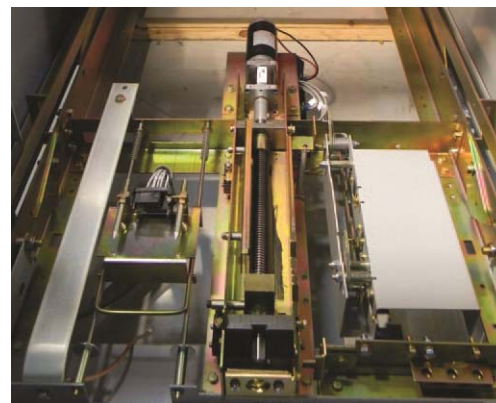
VCP-W MR2 motorized remote racking device provides a means of remotely inserting or removing any drawout circuit breaker used in VacClad-W switchgear, to help mitigate arc flash exposure.

Features:

- Factory installed and tested in VC-W switchgear
- Self powered when installed in Eaton switchgear
- External power provisions for use when system is de-energized
- Eaton handheld pendant is very user friendly
- Built in logic helps detect and identify potential problems, and keeps users from issuing unsafe commands to the circuit breaker
- Permissive circuit is available for customers to incorporate into their SCADA system.
- Modbus enabled for a systems approach to Motor control

Benefits:

- Reduced installation and maintenance effort
- No searching for or handling external racking device
- Rack all circuit breakers from a control room without ever entering the switchgear room

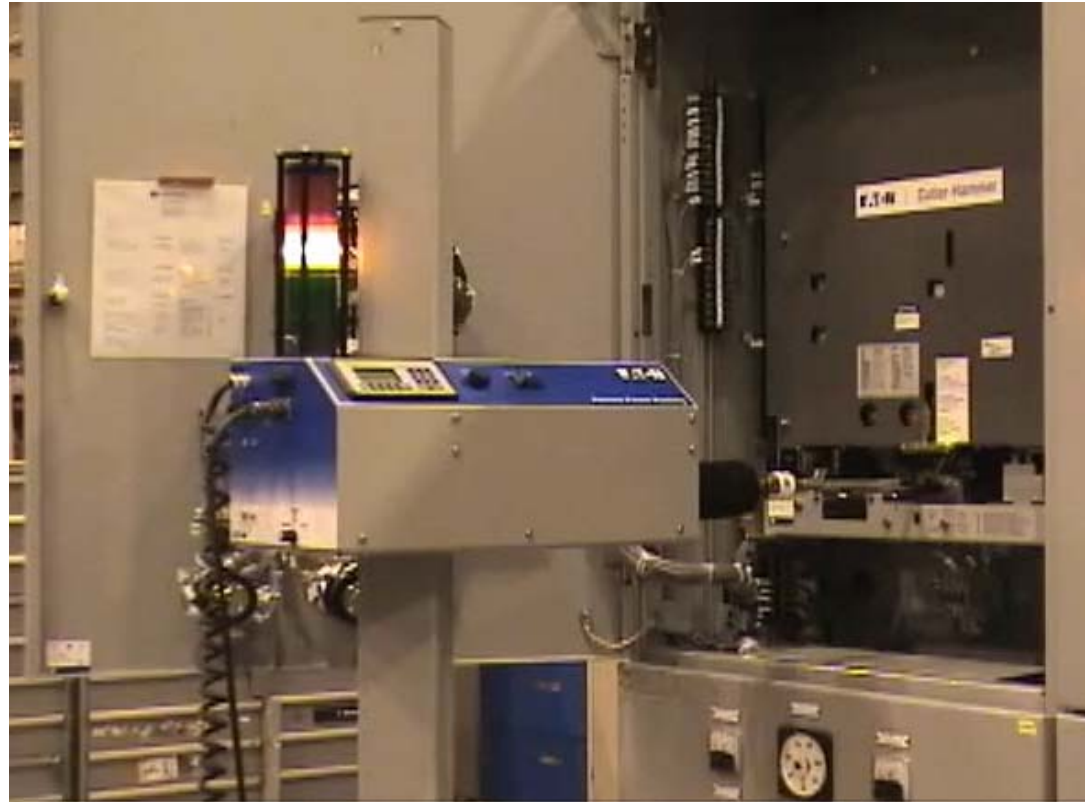


Arc Flash Safety Solutions

RPR-2 Closed Door Remote Racking

**Racks Most
Horizontal Draw
Out MV & LV
Power Breakers
With Rotational
Levering
Systems:**

- Vacuum
- Air-Magnetic



**Ideal For Large Concentrations Of Draw-out Breakers
Programmable for Up to 8 Breaker Types (Turns & Over-Torque)**

Arc Flash Safety Solutions

Ampgard ISO Switch Remote Operator



Ampgard MV Vacuum Starter

ISO Switch Remote Operator

- Mounting Provisions on Each Door
- Easy Mounting and Attachment
- 25 Foot Pendant
- Easy Detachment and Removal

Arc Flash Safety Solutions

MRR1000 & RPR-2 Remote Power Racking Device

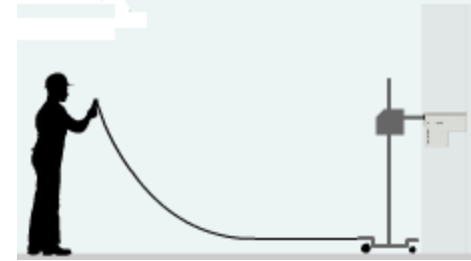
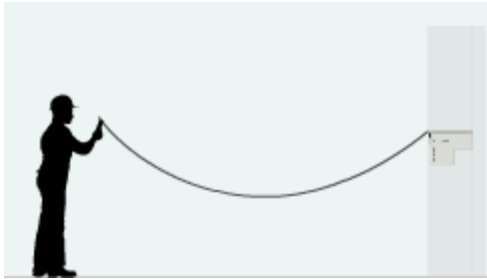
MRR1000



RPR-2

Arc Flash Safety Solutions

RotoTract™ - Closed Door Remote Racking (Size 1 – 5)



Simple RotoTract™ Device



RPR-2 Programmable Device

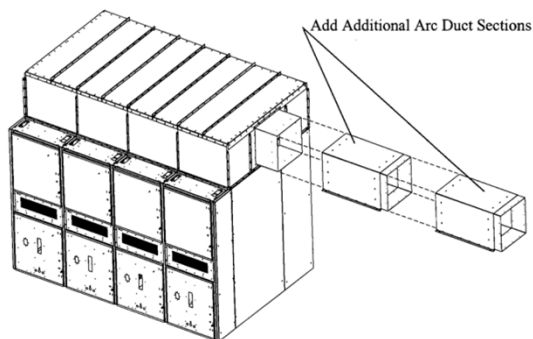
Redirect Fault Energy

5/15 kV Arc Construction



Arc Resistant MV Switchgear

It always has an Arc Plenum as shown below



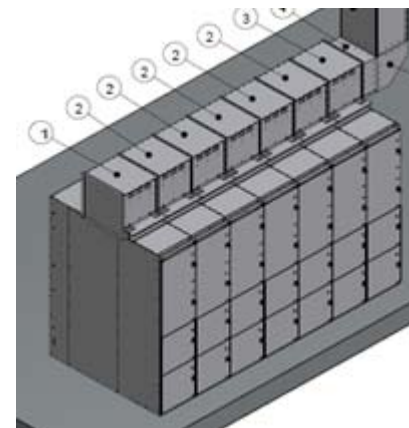
Arc Resistant MV Motor Control – AMPGARD

It always has an Arc Plenum as shown above



Arc Resistant LV Switchgear

Available w/o as shown above or w/ an Arc Plenum as shown below



Prevent Fault

High Resistance Grounding

- **HRG Units**
- **Typically Under 5 Amps**
- **Pulsing Contactor**
- **Many Options**
- **LV or MV**
- **Does Not Preclude PPE**
- **Lowers Probability of Accident**



FlashGard™ MCC The Ultimate Solution



BushingGard (InsulGard G2)

- Monitor Txmr Bushings
 - Capacitance
 - Power Factor



Monitor Insulation Integrity

- Switchgear
- Generators
- Motors

Safety Related Solution Offerings

Infrared Scanning Windows for LV/MV Assemblies



Continuous Thermal Monitoring

- Monitoring Connecting Joints on a PDU, Utilizing Plastic Bracket System
- Monitoring Individual Connections



Eaton Resources for AF Safety Solutions

- Eaton Application Engineers & Sales Engineers
- EESS District Operations Centers (DOC)
- PSE Group - Warrendale and Local PSE
- Eaton Websites: <http://es.eaton.com/arcflashsafetydemo/>
<http://www.eaton.com/Electrical/USA/MarketSolutions/Utilities/index.htm>

QUESTIONS ?

