Arc Flash Mitigation

Remote Racking and Switching for Arc Flash danger mitigation in distribution class switchgear.

CBS ArcSafe™
"Distance is Safety"

CBS NUCLEAR SERVICES, Inc.
A Group CBS Company

Distance is Safety

- We will discuss through examples of actual occurrences and possible scenarios the inherent dangers and best possible procedures for using Remote Racking/Switching and to mitigate damage during an arc flash or limit the occurrence.

- If procedures require the operation or racking of switchgear while energized these techniques and safety tools will limit exposure to arc flash and other dangers.

Arc Flash Basics

- An arc flash is measured is calories per cm^2. This value is referred to as the Incident Energy (E_I)
- Current industry standards require workers to wear PPE with a rating (ATPV) > than the E_I
- This is a 480V arc flash set up in a cubic box to simulate an MCC bucket or breaker cell by PSE&G
- E_I for this test was 51 cal/cm^2

Arc Flash Hazard

- There is no possible way to completely avoid arc flash hazards
- The preferred method for any electrical work is to de-energize the equipment you will be working on, in order to do this the equipment must be switched off, this action is considered an “Arc flash hazard”

Arc Flash Hazard

- 2009 NFPA 70E Definition: "Arc Flash Hazard" – A dangerous condition associated with the possible release of energy caused by an electric arc
  - FPN #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…..
  - FPN #2 – See table 130.7 (C)(9) for examples of activities that could pose an arc flash hazard

2009 NFPA 70E Tables

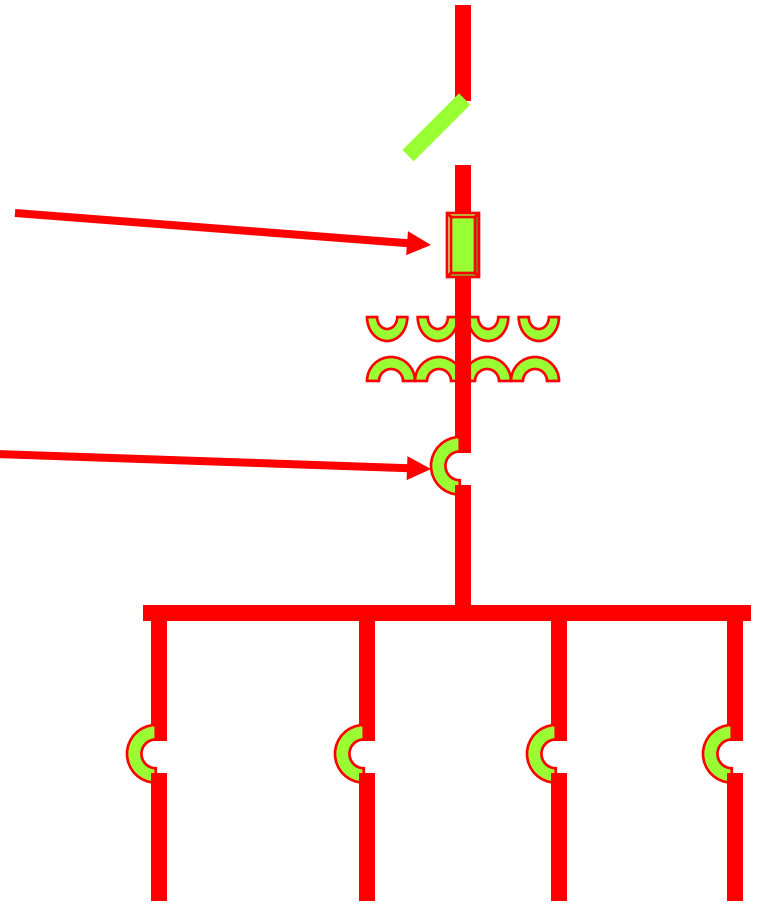
Task	2004 70E HRC	2009 70E HRC
Insertion or removal (Racking) of CB's from cubicles, doors open (600V class switchgear)	3	4
Insertion or removal (Racking) of CB's from cubicles, doors closed (600V class switchgear)	2	4
Insertion or removal (Racking) of CB's from cubicles, doors open (Metal clad switchgear 1kV-38kV)	4	4
Insertion or removal (Racking) of CB's from cubicles, doors closed (Metal clad switchgear 1kV-38kV)	2	4

NFPA 70E Tables

- Many companies decide to use the tables for PPE selection to save money and avoid doing an analysis.
- The tables can only be used if the available fault current and clearing times are known for the equipment to be worked on.
- The tables assume a maximum amp-cycle value. If these limits are not met an arc flash analysis is required.
- Example: 600V rated switchgear
  - Note 4: Maximum of 35kA available short circuit current available, maximum of up to 30 cycle clearing time

Table Limitations

- → Typical MV/LV substation
- → Fuses on MV side will not react quickly to secondary fault
- → Due to coordination issues the Main breaker usually does not employ INST trip
- → ST delays can be 0.3 seconds or longer
- → Arc Flash reduction switches or "Maintenance switches" can be effective



Flash Hazard Analysis

Arc Flash Protection (bolted fault) Boundary

NFPA eq.

	MVA $_{bf}$ = bolted fault MVA at point involved		2	MVA
	V = volts		480	volts
→	**%Z** = percent impedance based on transformer MVA		5	% Z
	t = time of arc exposure in **seconds,** (cycles / 60 cycles)		2	seconds
B- 2-1	I_{SC} = {{[MVA Base x 10^6] / [1.732 x V]} x 100 / % Z}			
	I_{SC} = **Short Circuit Current**	ANSWER	48,114	Amps
B- 2-2	P = 1.732 x V x I_{sc} 10^{-6} x 0.707^2			
	P = **Maximum Power** (in MW) in a 3-phase arc	ANSWER	19.994	MW
B-2-3.2	D_C = [**2.65** x MVA $_{bf}$ x t] $^{1/2}$			
	D_c = **Curable Burn Distance**	ANSWER	14.56	Ft
	D_c = **Curable Burn Distance**	ANSWER	174.72	inches

Arc Flash Protection (transformer) Boundary

NFPA eq.

	MVA = rating of transformer		2	MVA
	t = time of arc exposure in **seconds,** (cycles / 60 cycles)		2	seconds
B-2-3.3	D_C = [**53** x MVA x t] $^{1/2}$			
	D_c = **Curable Burn Distance**	ANSWER	14.56	Ft
	D_c = **Curable Burn Distance**	ANSWER	174.72	inches

→ Excel program using NFPA 70E Equations

→ Example:

- 2000kVA 480V transformer
- 2 second clearing time

D_C=14.56 ft

Flash Protection boundary

- The flash protection boundary determines at what distance from exposed live parts flash protection must be worn
- Distance is usually based on not exceeding 1.2 cal/cm^2 of heat energy on a persons skin
- 1.2 cal/cm^2 will cause a 2^{nd} degree burn of exposed skin in 0.1 second

Flash Hazard Analysis

Equation for Arc in Open Air

NFPA eq.

D_A = distance from arc electrodes, **inches** (for distances 18 in. and greater) — 36 inches

t_A = arc duration, **seconds** (cycles / 60 cycles) — 2 seconds

F = bolted fault short circuit current, in **kA** (for the range of 16 to 50kA) — 48 kA

B - 5.1 $E_{MA} = 5271 \times D_A^{-1.9593} \times t_A \times (0.0016 \times F^2 - 0.0076 \times F + 0.8938)$

E_{MA} = maximum open arc **incident energy**

ANSWER: 39.673 cal/cm²

Equation for Arc in a Cubic Box

NFPA eq.

D_B = distance from arc electrodes, **inches** (for distances 18 in. and greater) — 36 inches

t_B = arc duration, **seconds** (cycles / 60 cycles) — 2 seconds

F = bolted fault short circuit current, in **kA** (for the range of 16 to 50kA) — 48 kA

B - 5.2 $E_{MB} = 1038.7 \times D_B^{-1.4738} \times t_A \times (.0093 \times F^2 - .3453 \times F + 5.9675)$

E_{MB} = maximum 20 in. cubic box **incident energy**

ANSWER: 114.3091 cal/cm²

→ A 48 kA fault with a 2 second clearing time at 36”

→ E_I will be:

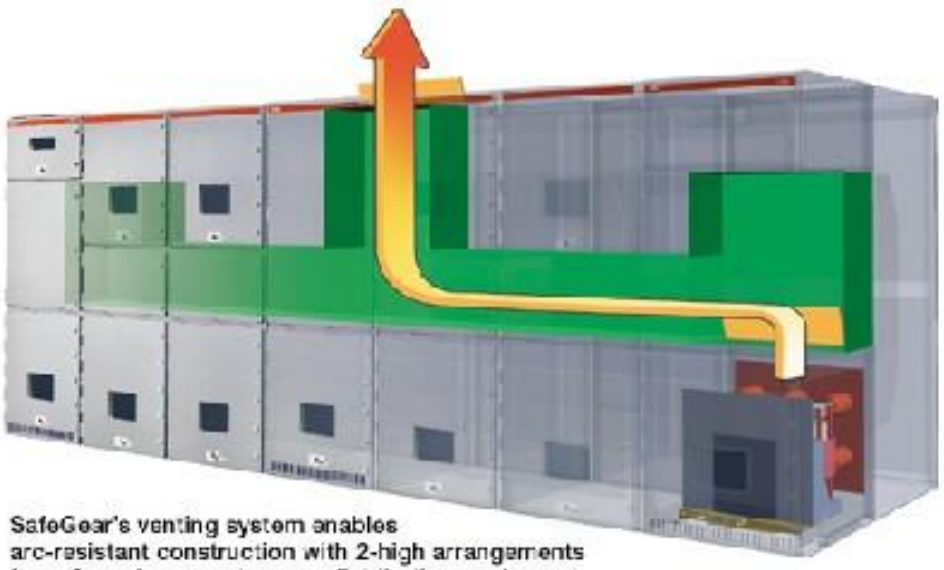
- 39 Cal/cm² in open air
- 114 Cal/cm² in a cubic box

PPE Limitations

- → No way to re-test or verify the ATPV rating
- → Expensive to purchase and maintain
- → Little protection from arc blast pressures, not recommended for >40cal/cm^2 exposure
- → Cumbersome, vision and mobility is limited

Mitigation

- Arc resistant switchgear is available that redirects the arc away from the operator using a system of channels and flaps
- Existing switchgear may also be modified to be arc resistant
- Must meet the requirements of IEEE C37.20.7



SafeGear's venting system enables arc-resistant construction with 2-high arrangements for safe and compact power distribution equipment.

Mitigation

- 2 basic concepts for arc flash mitigation:
  - Reduce the total amp-cycles of the arcing fault
  - Increase the distance from the arc to the worker
- Limiting fault current seems to be a simple solution
- Keep in mind that reducing the fault current may increase the clearing time of the OCPD and may actually increase the hazard
- Current limiting fuses are only effective if the arcing current is in the current limiting range

Validity of Arc Flash Analysis

- → The results of the arc flash analysis, or the HRC from the tables assume the OCPD will clear the fault within the manufactures published TCC
- → A failed OCPD, or even a slow one, will result in higher Incident Energies than the workers PPE is rated for
- → New 2009 70E Article 205.3 – General Maintenance Requirements – OCPD's shall be maintained IAW the manufactures instructions or industry standards
- → FPN: Refer to NFPA 70B or ANSI/NETA MTS for guidance on maintenance frequency, methods, and tests

Validity of Arc Flash Analysis

- → Over 30% of low and medium voltage power circuit breakers tested that have been in service for more than 24 months in industrial applications will not perform to specification when "as found" trip tests are performed.
- → After exercise and operation, cleaning and proper lubrication this is reduced to less than 12 %.
- → This data comes from a cross reference of Group CBS company results compiled over 2000 breakers.

Validity of Arc Flash Analysis

- Assume a worker is racking out a 600V feeder breaker for the purpose of LOTO.
- Arc Flash label requires the worker to wear 40 cal/cm^2 flash suit

Equation for Arc in Open Air

NFPA eq.

D_A = distance from arc electrodes, **inches** (for distances 18 in. and greater) — 24 inches

t_A = arc duration, **seconds** (cycles / 60 cycles) — 0.5 seconds

F = bolted fault short circuit current, in **kA** (for the range of 16 to 50kA) — 36 kA

B - 5.1 $E_{MA} = 5271 \times D_A^{-1.9593} \times t_A \times (0.0016 \times F^2 - 0.0076 \times F + 0.8938)$

E_{MA} = maximum open arc **incident energy** — ANSWER: 14.028 cal/cm^2

Equation for Arc in a Cubic Box

NFPA eq.

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B - 5.2 $E_{MB} = 1038.7 \times D_B^{-1.4738} \times t_A \times (.0093 \times F^2 - .3453 \times F + 5.9675)$

E_{MB} = maximum 20 in. cubic box **incident energy** — ANSWER: 26.8335 cal/cm^2

Validity of Arc Flash Analysis

- → Main breaker fails to trip
- → Worker may be exposed to 107 cal/cm^2, the 40 cal/cm^2 flash suit will fail
- → The worker did nothing wrong, who is at fault?

Equation for Arc in Open Air

NFPA eq.

D_A = distance from arc electrodes, **inches** (for distances 18 in. and greater) — 24 inches

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B - 5.1 $E_{MA} = 5271 \times D_A^{-1.9593} \times t_A \times (0.0016 \times F^2 - 0.0076 \times F + 0.8938)$

E_{MA} = maximum open arc **incident energy**

ANSWER: 56.110 cal/cm^2

Equation for Arc in a Cubic Box

NFPA eq.

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E_{MB} = maximum 20 in. cubic box **incident energy**

ANSWER: 107.3341 cal/cm^2

Case Study 1 - Overview

- This accident occurred on Jan 5, 1993 at Gulf States Electric Utilities in Beaumont, TX
- When company and contract electricians forced a 5 kV Federal Pacific circuit breaker from the cell after it became lodged in the structure, the resulting arc flash killed 2 employees and severely burned 3 others.
- All of the technicians that were killed and badly burned were wearing arc flash PPE. This arc blast was un-survivable with any known PPE.
- Increasing the working distance through the use of remote racking and switching devices would have saved these people from injury.

Case Study 1 - Details

- The 5 kV breaker was moved from a switchboard in an adjacent unit that was down.
- The switchboard it was installed in that day was several years newer but the same type, however, the MOC operator was located at a different height.
- When the breaker was given a close command it tried to close but was jammed half way through the close cycle.
- The day shift went home and left the instructions for contract electricians to get the breaker out and locate the issue.
- When they removed it, the breaker continued the close command and a tremendous arc flash occurred.

Case Study 1 - Prevention

- → This accident could have been avoided with proper training and operational know how.
- → When any obstruction is encountered the first step is to schedule a shutdown and investigate the problem in an off line scenario.
- → Never trouble shoot this type of blocked operation mechanical failure online.
- → Remote devices should always be used when a problem is suspect to take the equipment offline

ArcSafe Solutions – RRS2

→ RRS-2 Installation and Removal

Case Study 2 - Overview

- March 4, 2009, at the Jubail Project in Riyadh, Saudi Arabia
- Three workers were removing a 480-volt, molded-case circuit breaker from the bucket of an energized Motor Control Center (MCC) when an electrical arc flash occurred, severely injuring them.

Case Study 2 - Details

- All three sustained first- and second-degree burns and were hospitalized following the accident.
- Myth: Switchgear is designed with arc flash containment in mind
- MCC Arc Flash

Case Study 2 - Prevention

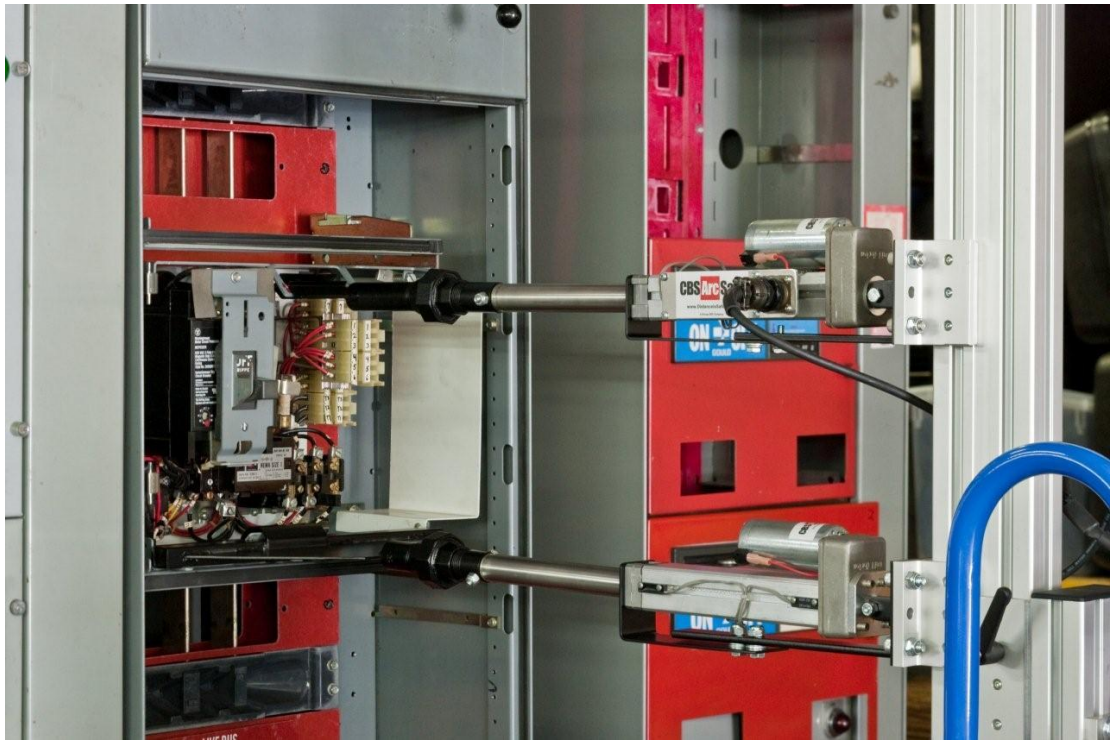
- → The system should have been de-energized to perform this task
- → If de-energizing was not “feasible” the bucket could have been extracted remotely

Case Study 2 - Prevention

- Remote switching actuators could have opened the molded case breaker.
- RSA-37 Siemens MCC

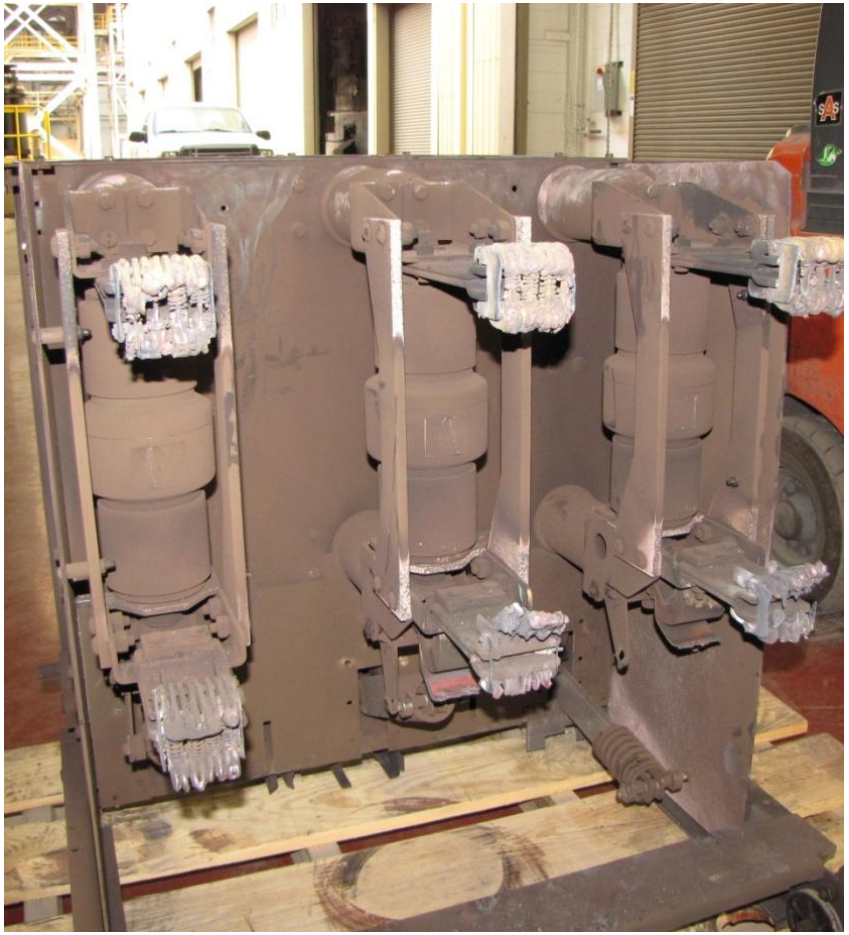
Case Study 2 - Prevention

- Remote Racking Bucket Extractor could have removed the MCC bucket safely
- RRS-2 Bucket Extractor



Case Study 3 - Overview

- On May 23rd, 2009 a power plant in the Midwest experienced a severe arc flash incident
- The incident occurred while racking in a closed Siemens 15 kV GMI breaker with a faulty interlock
- When the (closed) breaker contacted the bus, a large arc flash occurred



Case Study 3 - Details

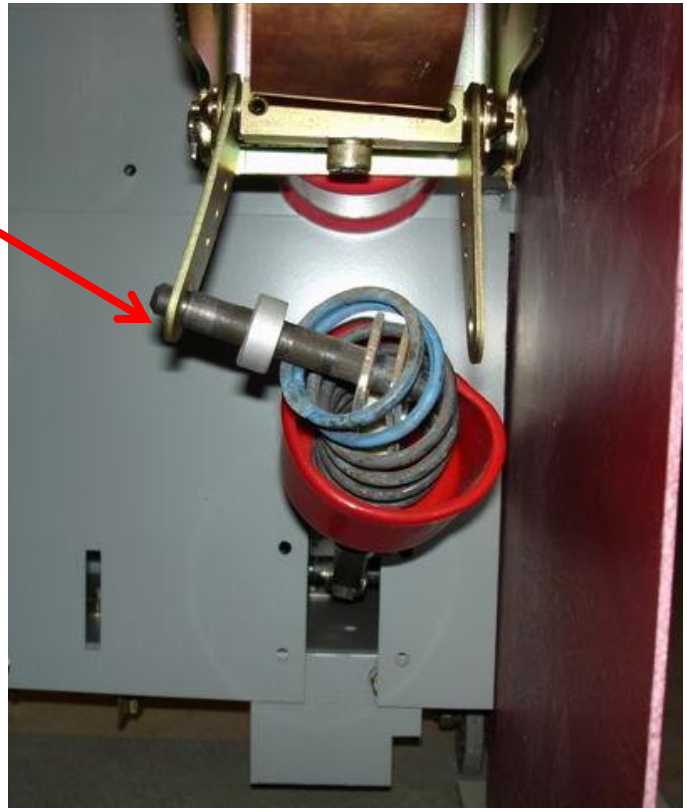
- → The breaker was being racked in remotely (Wireless), the operators were in another room and there were NO injuries of any kind.
- → The RRS-1 was used after the arc flash incident to remove the damaged GMI from the cell for evaluation.
- → Plant personnel that were present are convinced that lives were saved that day

Case Study 3 - Solution

→ RRS-1 with camera and light

Lesson Learned

- This Siemens GMI 15 kV Vacuum Breaker has a broken push rod, the breaker shows open however on pole is closed
- This was concealed from our technicians behind the faceplate
- GCBS procedure is to open the mains and work from a dead buss when possible.
- This procedure saved our technician from a possible injury from the arc flash that would have occurred.



Summary

- Each year, over 2,000 arc flash victims are sent to burn centers
- It is rarely one thing that will defeat the system but often a series of events that lead to a failure of systems and procedures.
- These are often not considered, or determined to be so remote that they are not planned for.
- Broken components, safety interlocks and foreign matter can stack the cards against you.

Summary

- → People make mistakes, that's why we call them accidents
- → OCPD's can fail, PPE can fail, enclosures can fail
- → Increasing working distance is the best, safest, most fool proof, and in many cases the most cost effective mitigation method

Conclusion

- → Routine circuit breaker maintenance can help prevent failures and ensure the accuracy of the arc flash study
- → When dealing with an actual Arc Flash incident mitigation is distance… “Distance is Truly Safety”
- → Q&A