Safety By Design

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IEEE CANADA 2013

Arc Flash Equation Open A (Above 600 Volts)

- $E = (793 \times F \times V \times t_A)/D^2$

- E = Incident Energy in cal/cm²
- F = Bolted fault short circuit current in kA
- V = phase-to-phase voltage in kV
- t_A = Arc Duration in Seconds
- D = Distance from the arc source in inches

Safety by design Substation Goal

Design a Substation where all tasks identified in NFPA 70E tables for MCC and SWGR will be hazard / risk category 1 or 0

i.e.

Qualified technicians rely on PPE as a last ditch mean of protection only really needed for measuring for absence of voltage and applying safety grounds where not using ground trucks

Safety and Design Considerations

- Arc Flash Boundary Identified
- Arc Resistant
  - MV Switchgear
  - LV Switchgear
  - MV motor Control
- Rear Door Interlock
- Remote Racking
- Mimic Bus
- PPE Storage in the PCR
- Grounding truck

Safety by Design Considerations

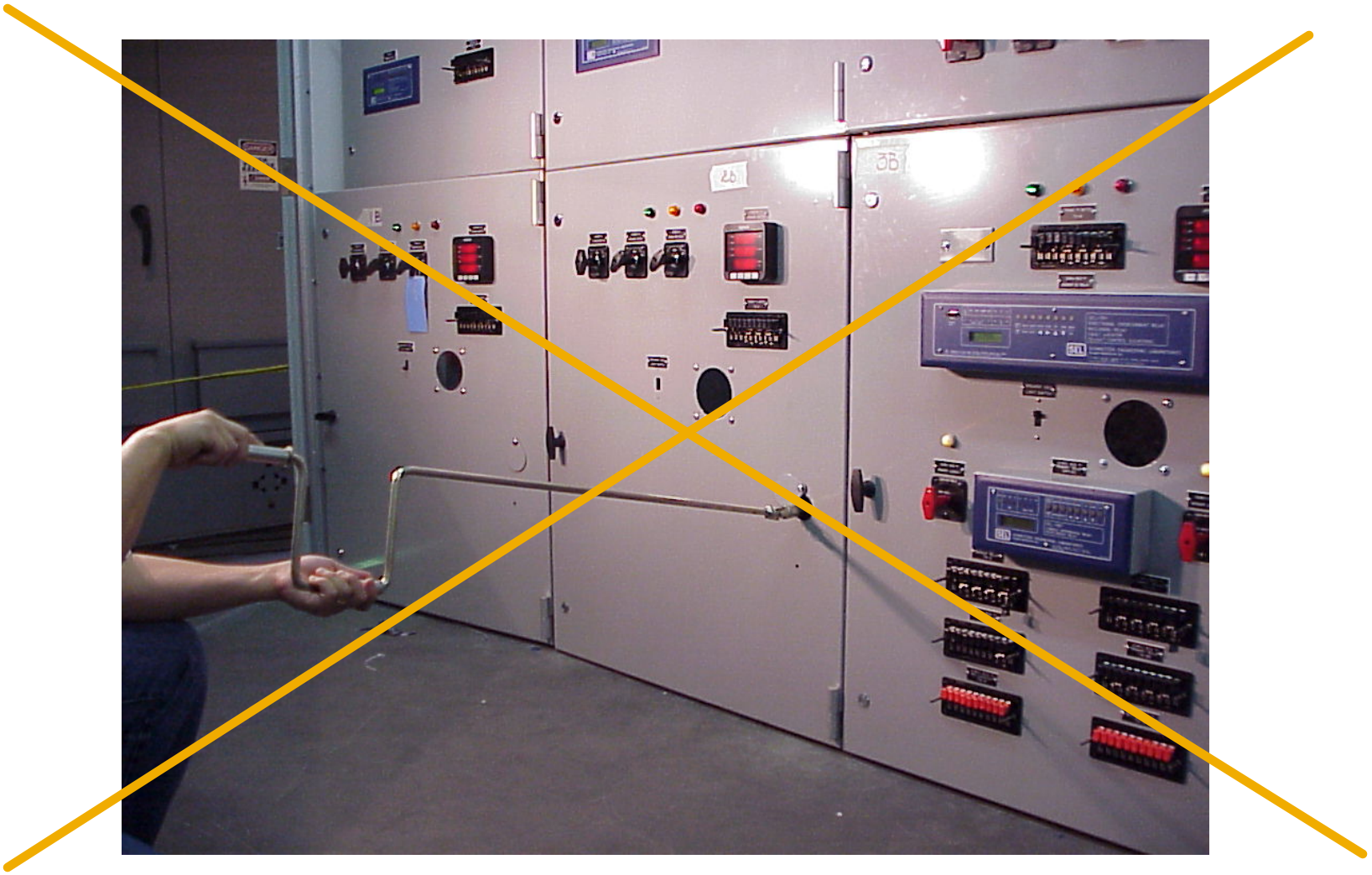
- High Resistance grounding for 5kV and below
- Med Resistance grounding for 15kV
- Touch safe terminals
- Labeling

Enhanced Safety Options

- Complete Short Circuit , Coordination and Arc Flash Study
- Field Service installation supervision
- Smart Substation
- Infrared ports
- Instantaneous relaying
- Factory Training

13.2kV 25kA Incident
assume cleared by fuse at switch

Through door racking of standard equipment



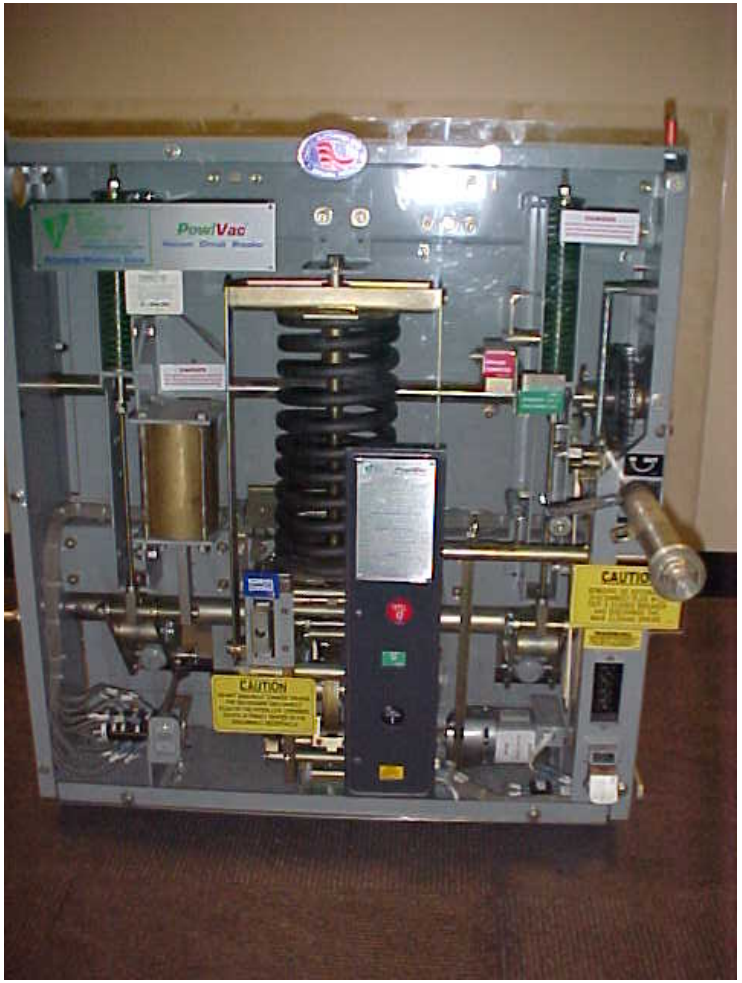
Remote Racking

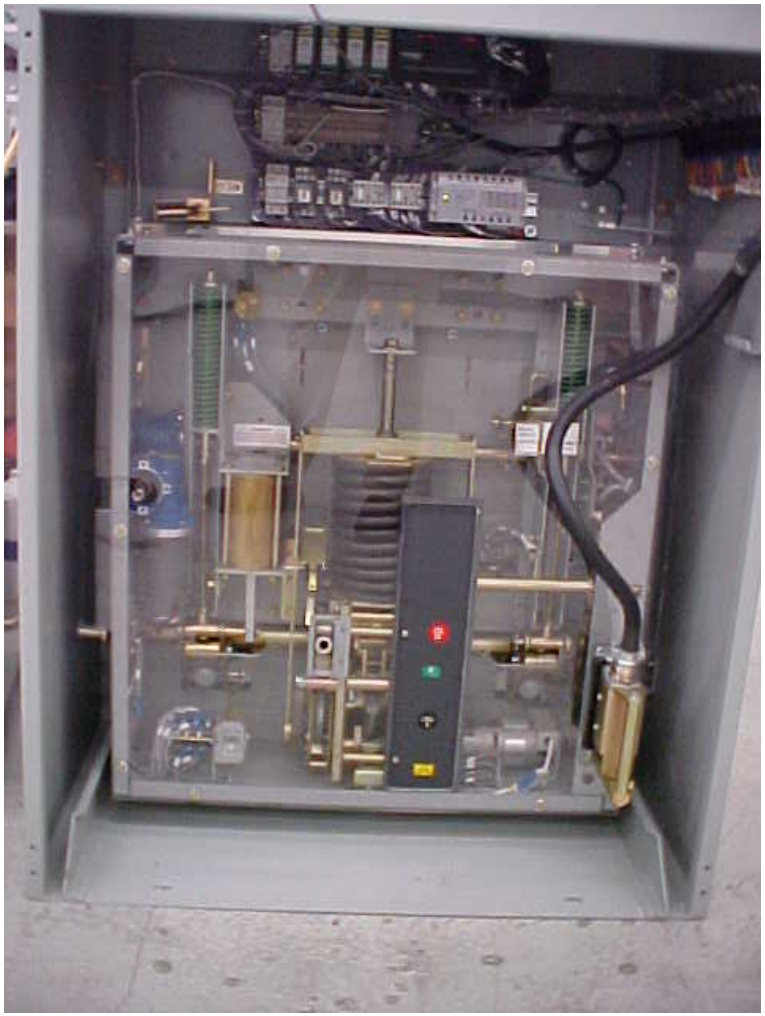
Racking 50-DHP-VR

Remote Open / Close

- Cannon Plugs added to the front of the switchgear
- One control station used to open and close breakers

Closed Door Racking

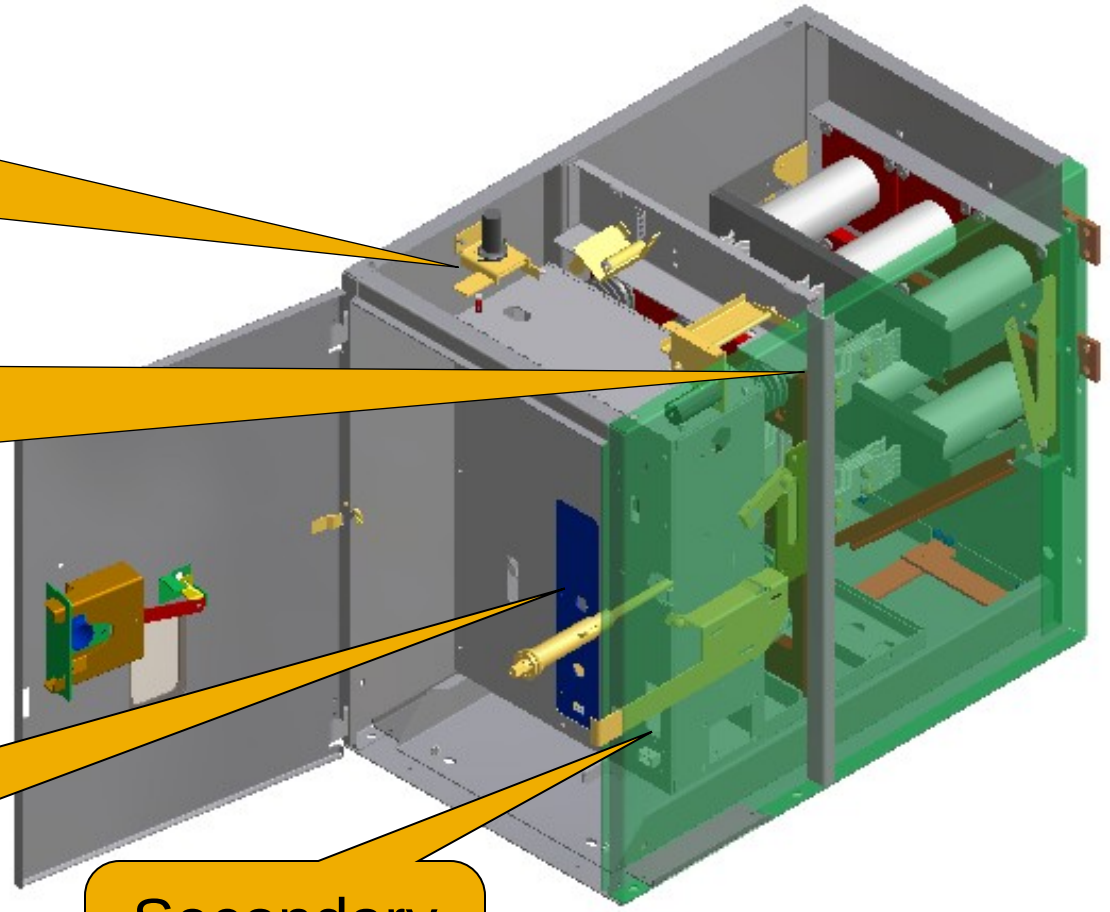




Labeling

- Front of gear mimic
- Protective "One Line" Nameplate
- Descriptive labels for components
  - Not just labeling fuse as FU-2 but label FU-2 CB Close Circuit
- Labeled shutters
- Cable compartment nameplates

Breaker Compartment Hazards



TOC (Truck Operated Contacts)

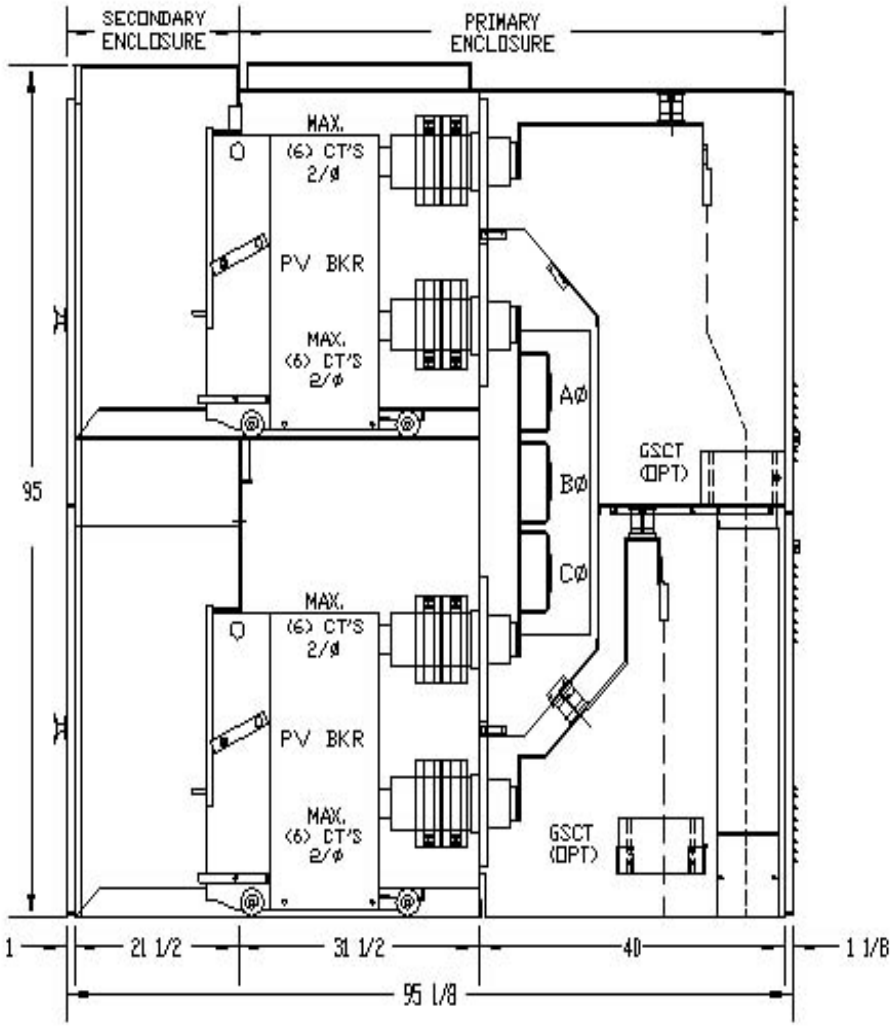
MOC (Mech Operated Contacts)

Circuit Breaker Racking

Secondary disconnect

MV Swgr

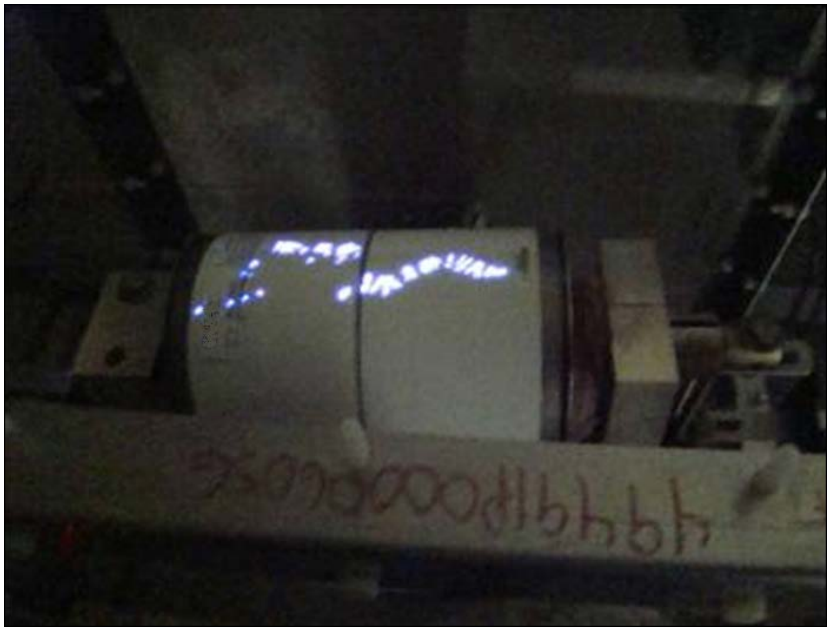
- Long creep paths to help eliminate tracking faults
- Minimal phase to phase supports
- Minimize hot spots
  - Conductor size
  - Surface area
  - Air flow rate
- Racking method
  - Assure alignment
  - Maintainable

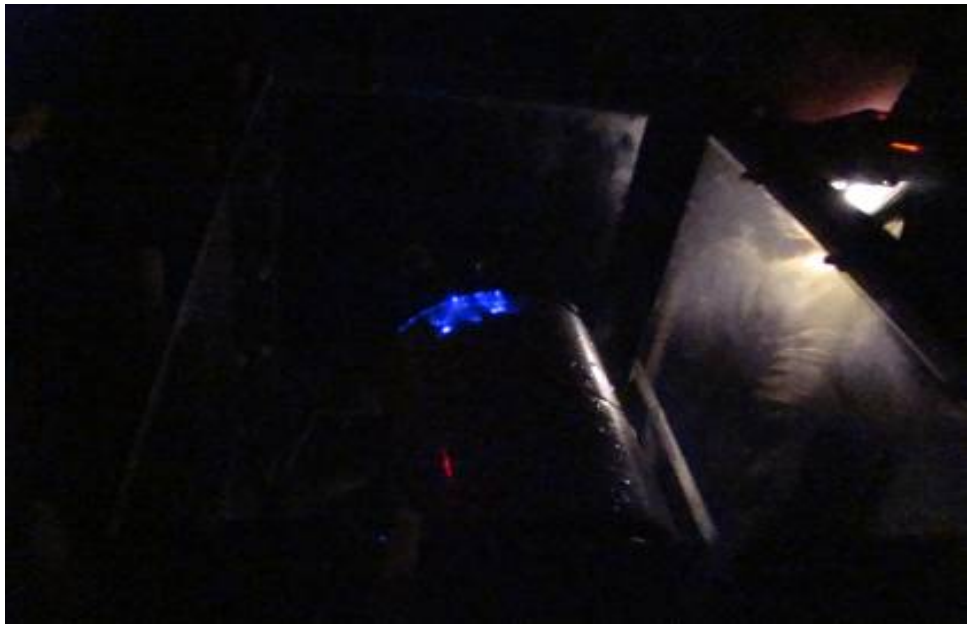


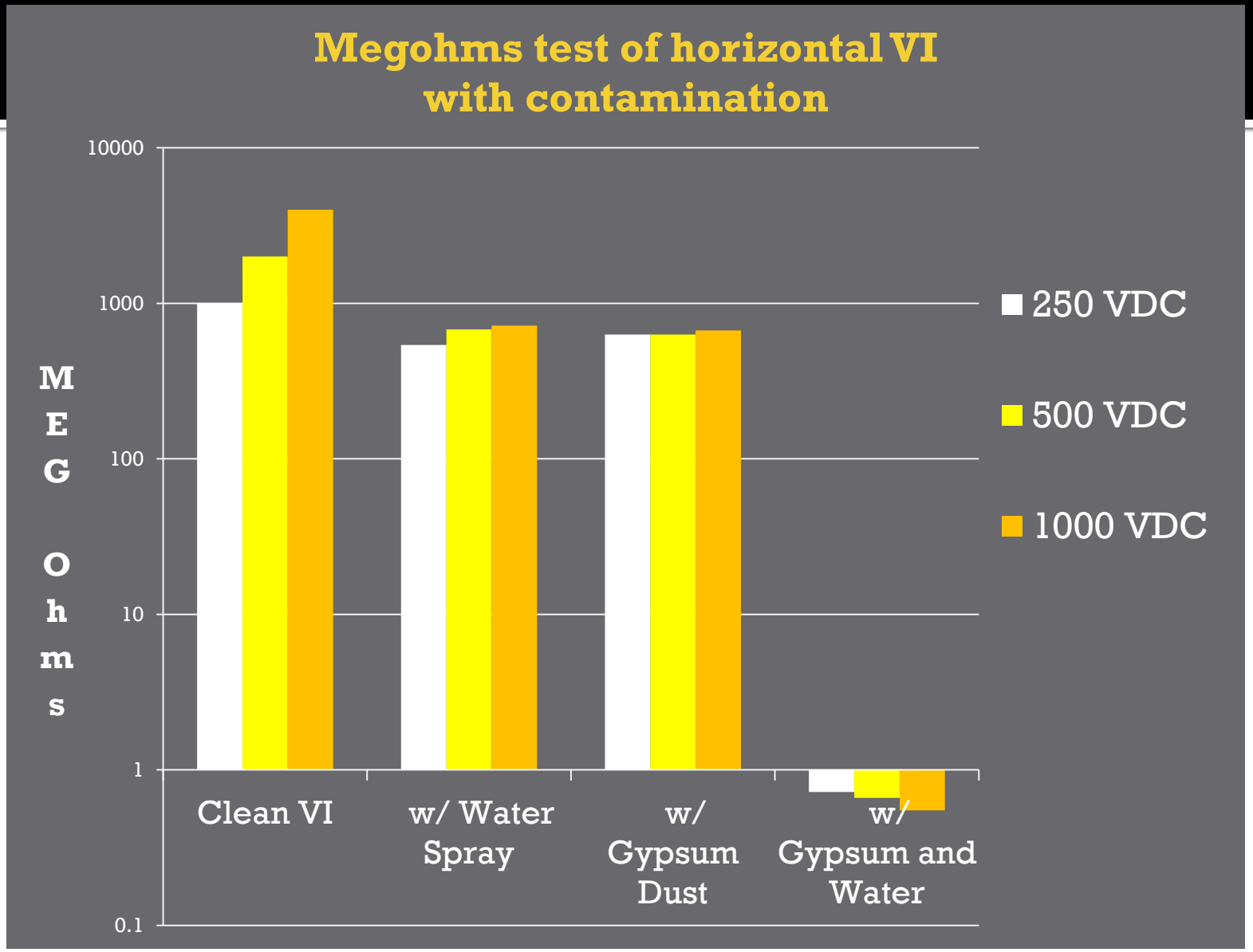
Contamination and Aging

- Reliability center maintenance
- Climate controlled Substation
- Anti-condensation heaters
- Long creep paths
- Thermal limits
- Mechanism aging
  - Too many operation – mechanical wear
  - Too few operation – mechanical freezing

Visible corona across a contaminated VI

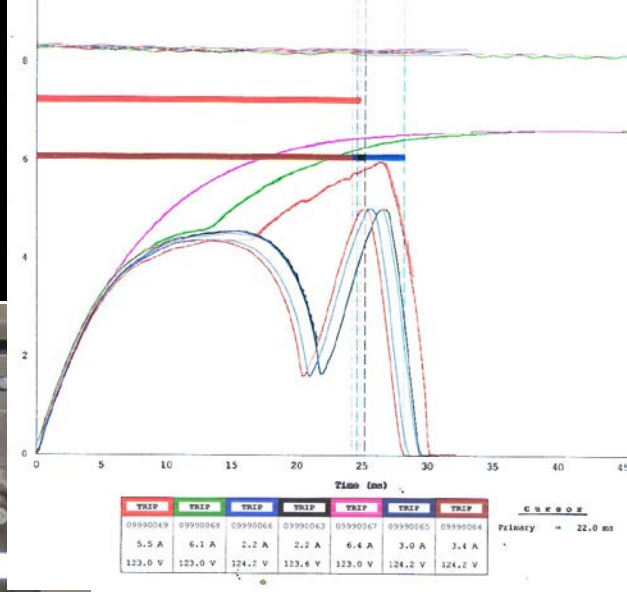





Megohms test of horizontal VI with contamination
MEG Ohms
10000
1000
100
10
1
0.1
Clean VI
w/ Water Spray
w/ Gypsum Dust
w/ Gypsum and Water
250 VDC
500 VDC
1000 VDC

Failure Mechanisms

- Dielectric System
  - Temperature
  - Altitude
  - Contamination
  - Partial Discharge
- Mechanical System
  - Temperature
  - Contamination



Additive Effective – Surface Flashover

- Non-uniform Electrical stresses
  - Localized partial discharges
- Elevated temp and ozone
  - Reactions with the polymeric insulation
- Low impedance high stress areas
  - Free electrons
  - Less stable molecules
- Electron Avalanche

Additive Effects - Flashover in Air

- Per design low level voltage stress limits

1" = 20kV

  - Few free electrons
  - No current flow
- As field strength increase or chemical bonding
  - More free electrons and more collisions
- Process continues resulting in conductive path
- Resulting in electron Avalanche

Failure Mechanism – Dielectric System

- Contamination
- Condensation

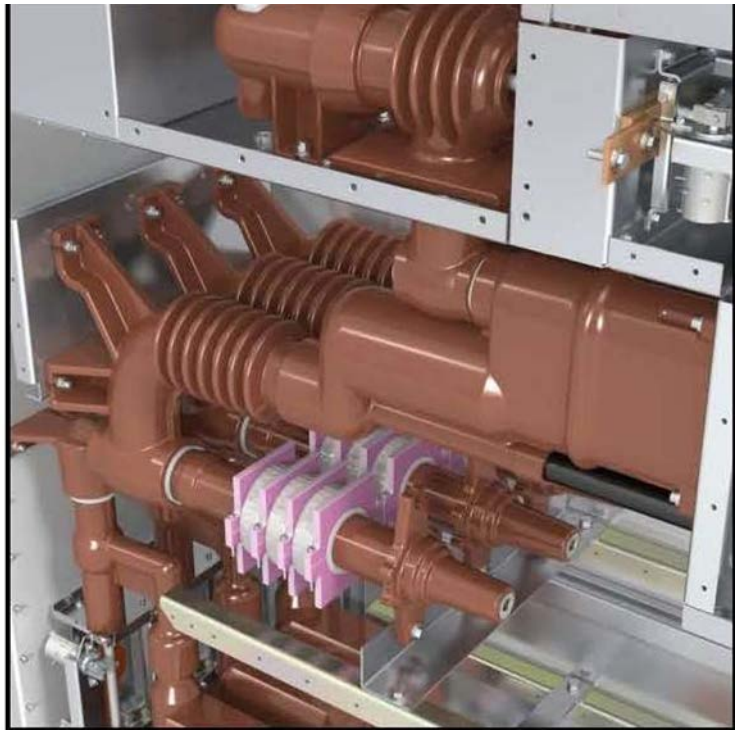
Substation

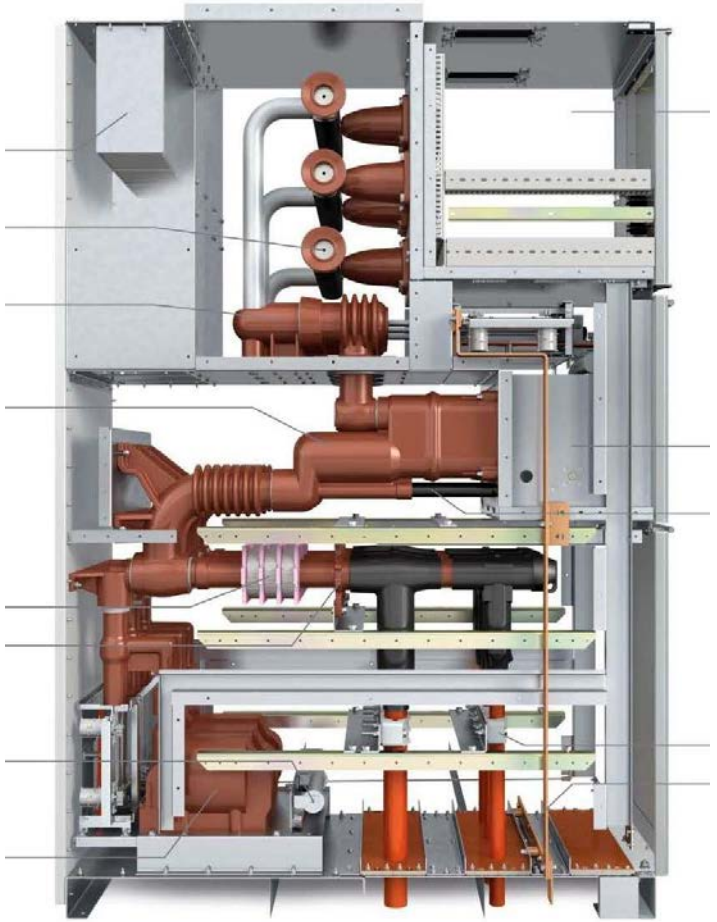
- Climate control of substations
- Chemical filtration where required by coupons tests
- Windowed door to allow radio communication and door safety

Plug and play vertical sections

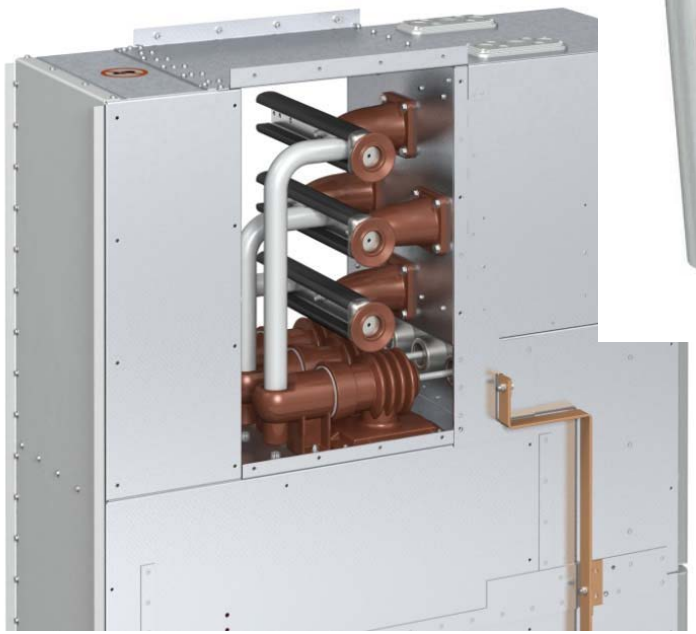
- Only a 630A, 20kA device at this time

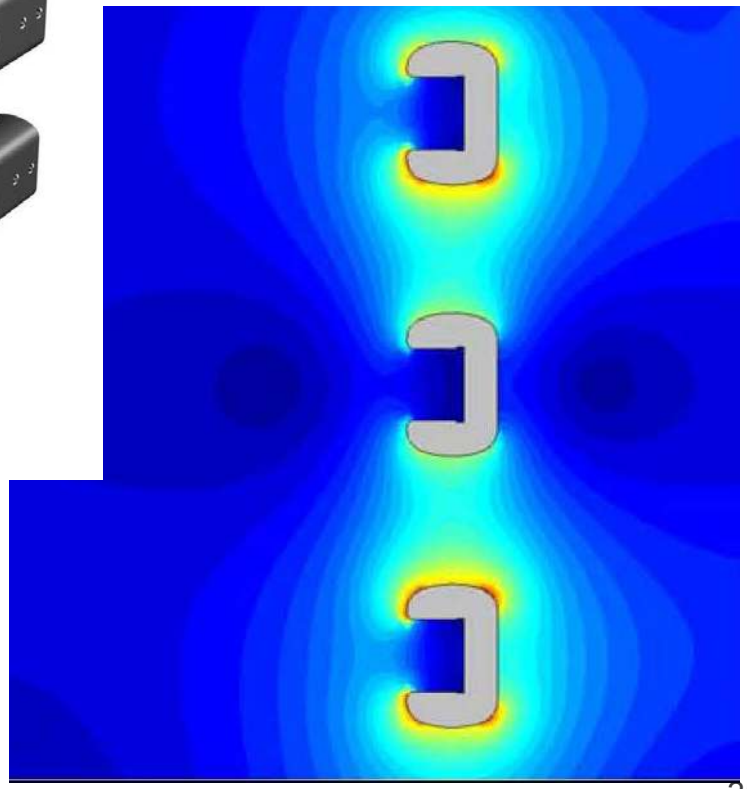
Minimized bare copper helps prevent arcing fault





Managing the E Field

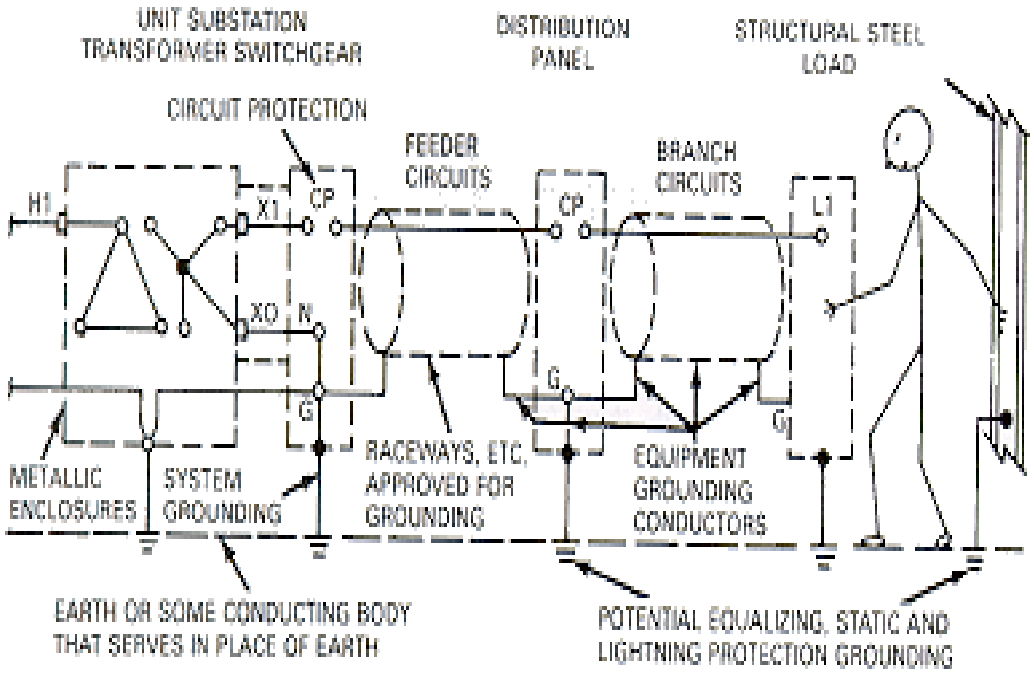




System Grounding

Risk of a Poor Grounding System

- Panel is 20 Ω to ground
- Transformer ground
  = 10 Ω to ground
- No ground return path
- Ig=Ground Fault

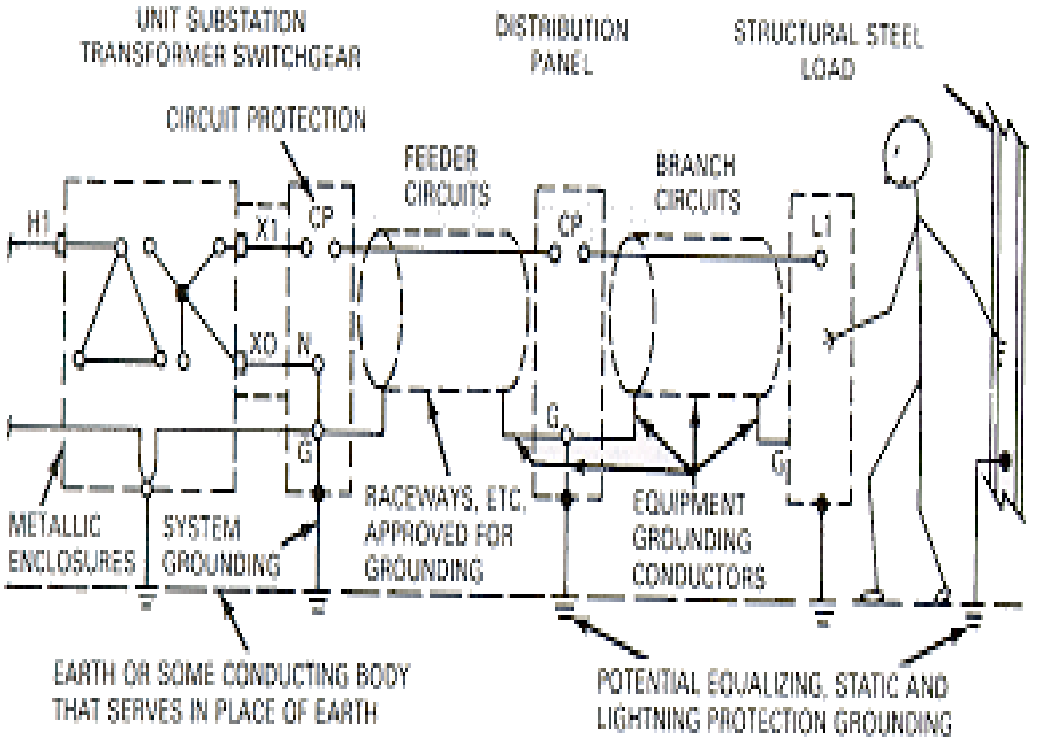


$$Ig = \frac{\text{Volts}}{\text{R of the ground path}} = \frac{277\text{Vac}}{20\ \Omega + 10\ \Omega} = 9.233\text{A}$$

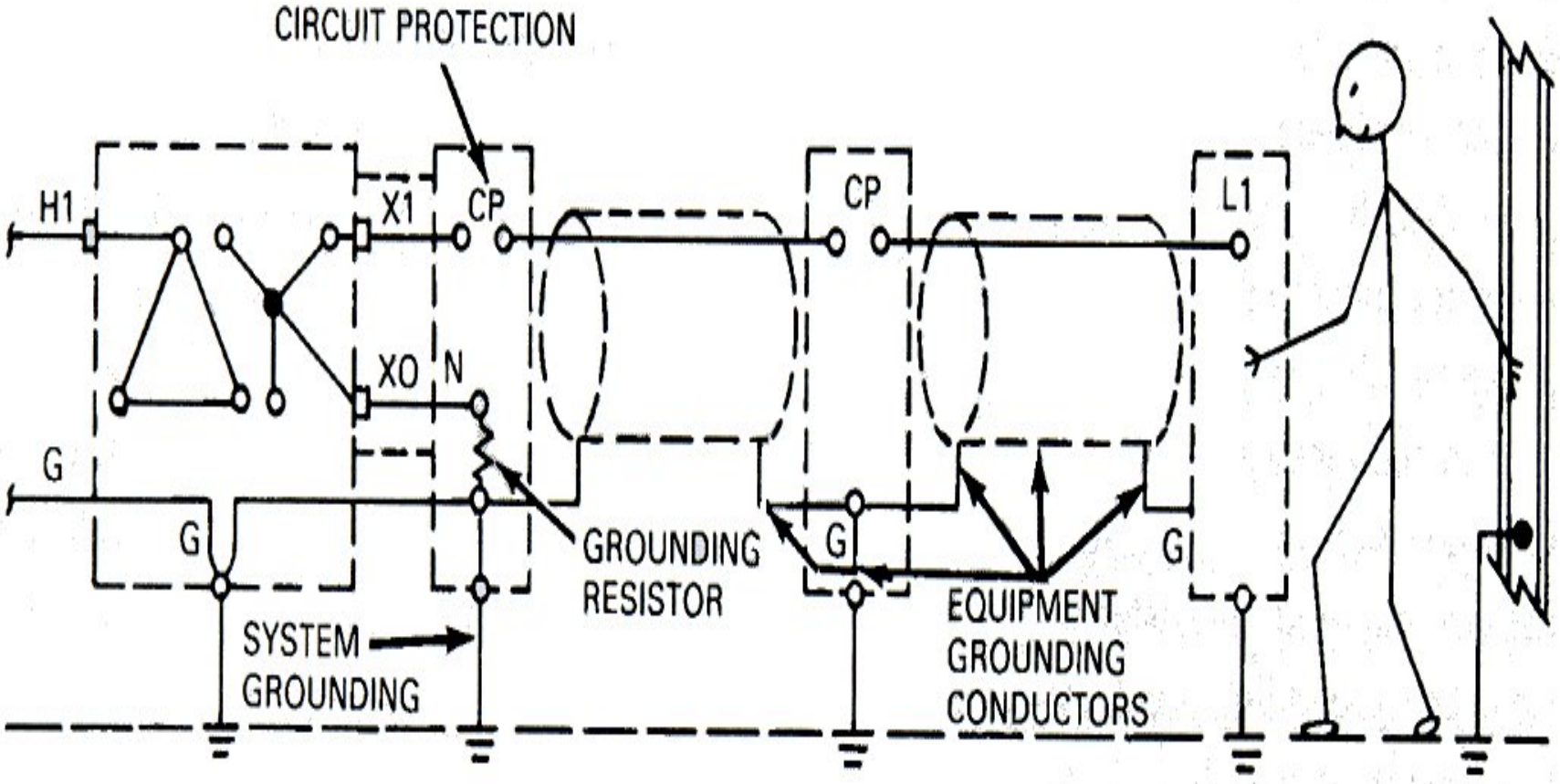
Panel touch potential with 9.23Amps of fault current

- V=IgR
- V=(9.233A)(20 Ω)
- V= 184Vac

- If a good return path - 0 volts across panel



Resistance Grounded System

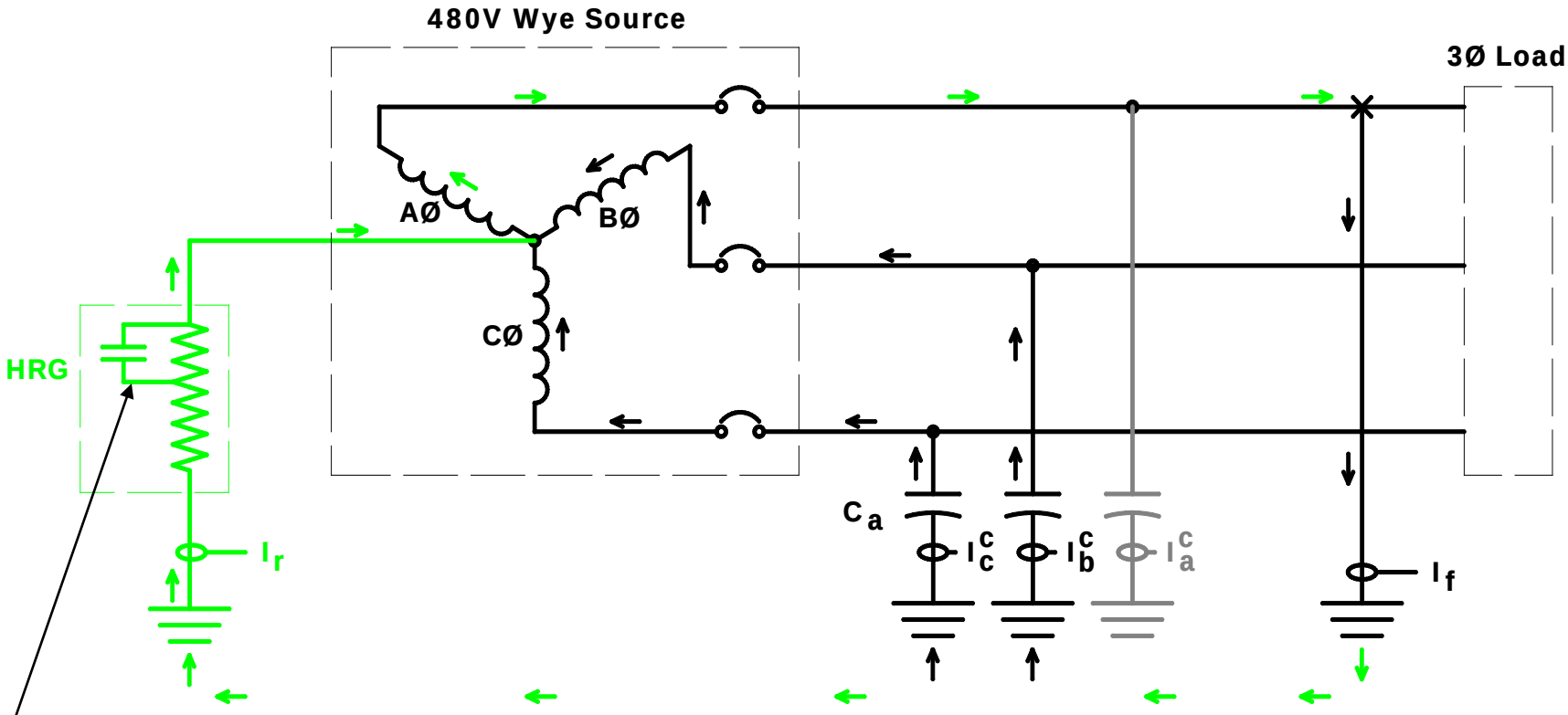


High Resistance Grounding

- Available in 4160, 2300 and LV
- Arc Energy Reduction for Effectively Grounded
- Fault Location for Ungrounded
- Reduced Equipment Damage
- Minimize fault escalation
- Minimize ground fault arc fault energy
- Process Ride Through

High Resistance Grounding

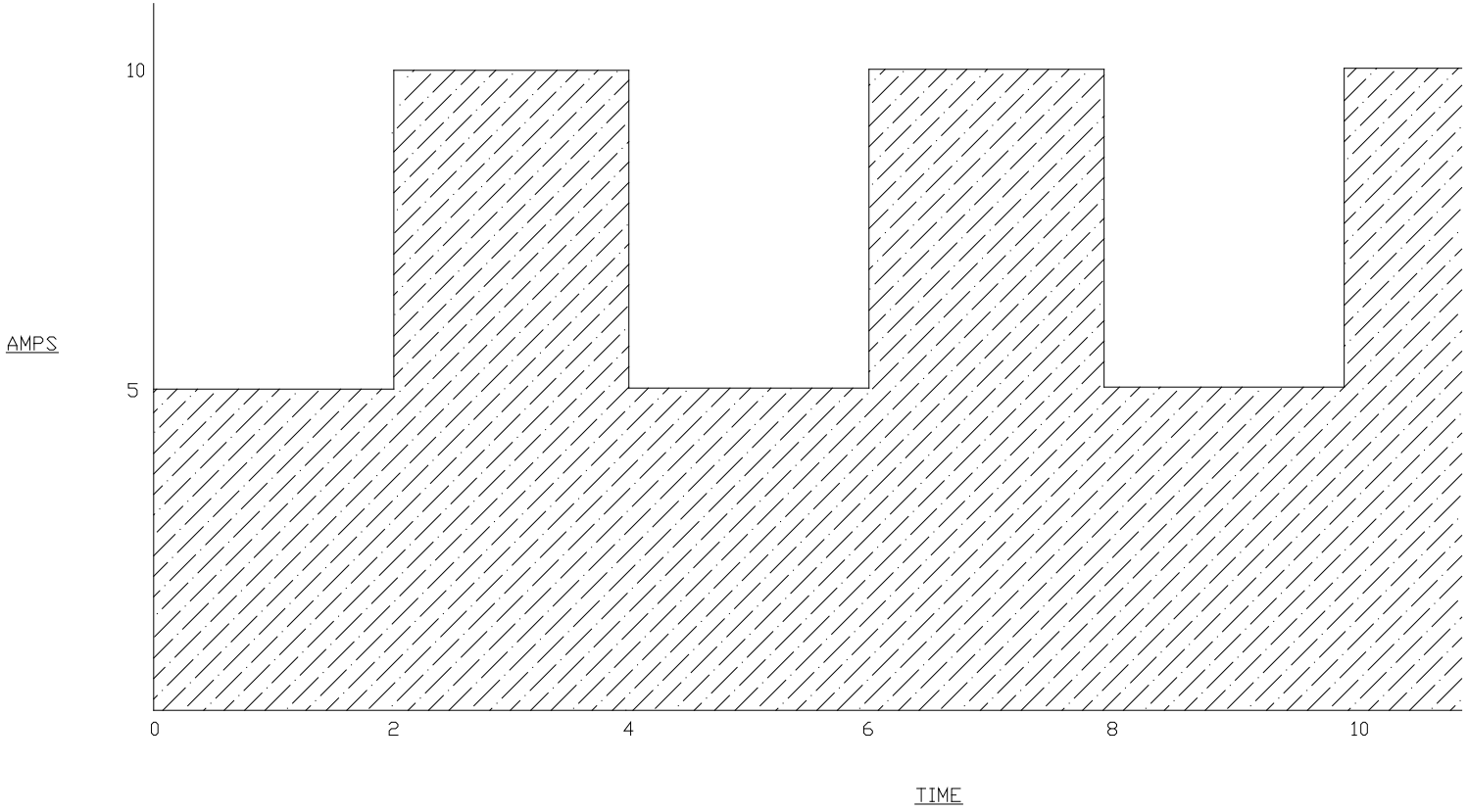
- Another advantage of return path: ground fault location



Contactor shorts out part of the resistor changing the resistance, hence, changing the current. Ground fault current now is a pulse signal that allows for detection!

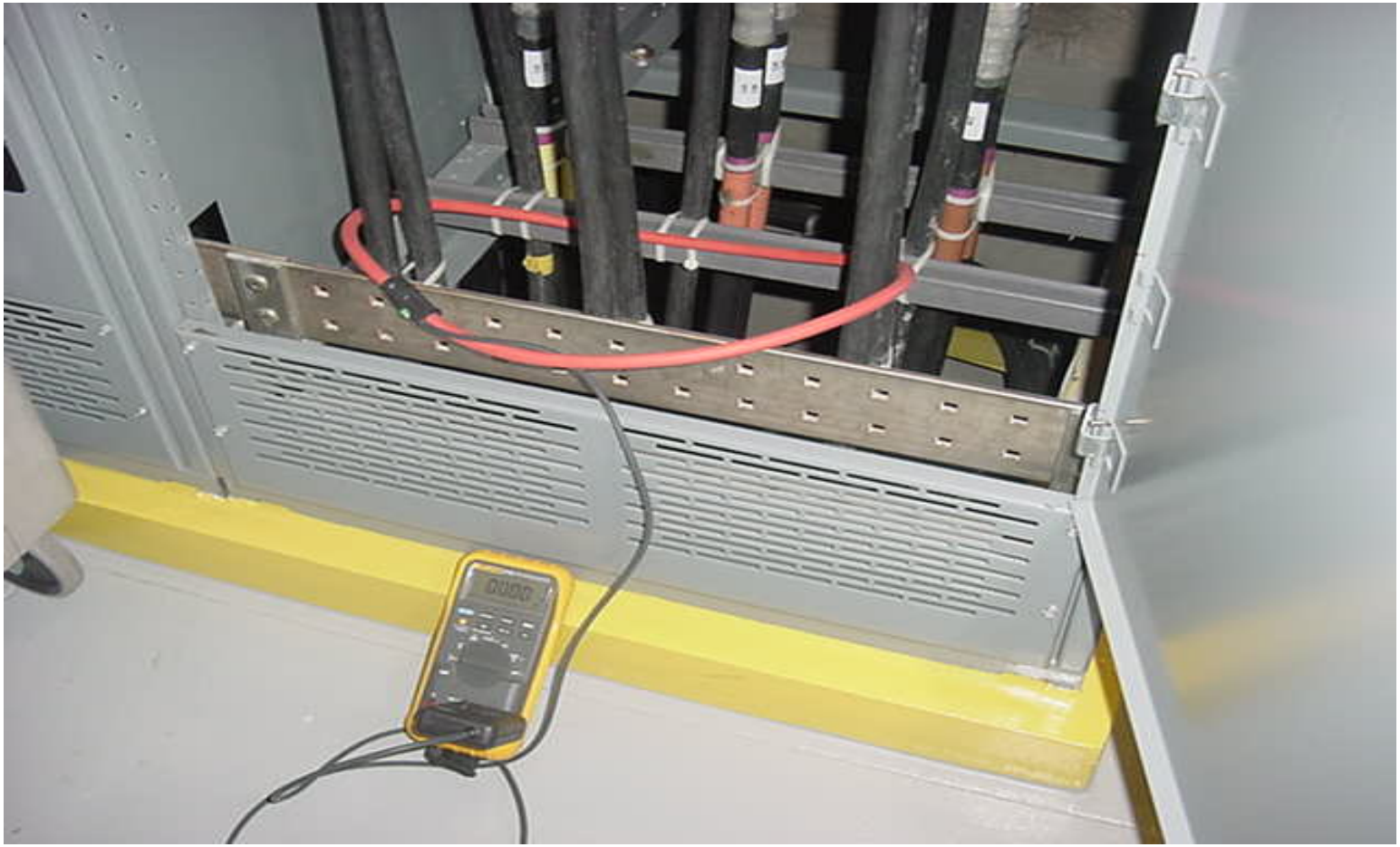
High Resistance Grounding

- Contactor shorts out ½ resistance, thus, doubling current to 10A at ~30 pulses / minute.



High Resistance Grounding

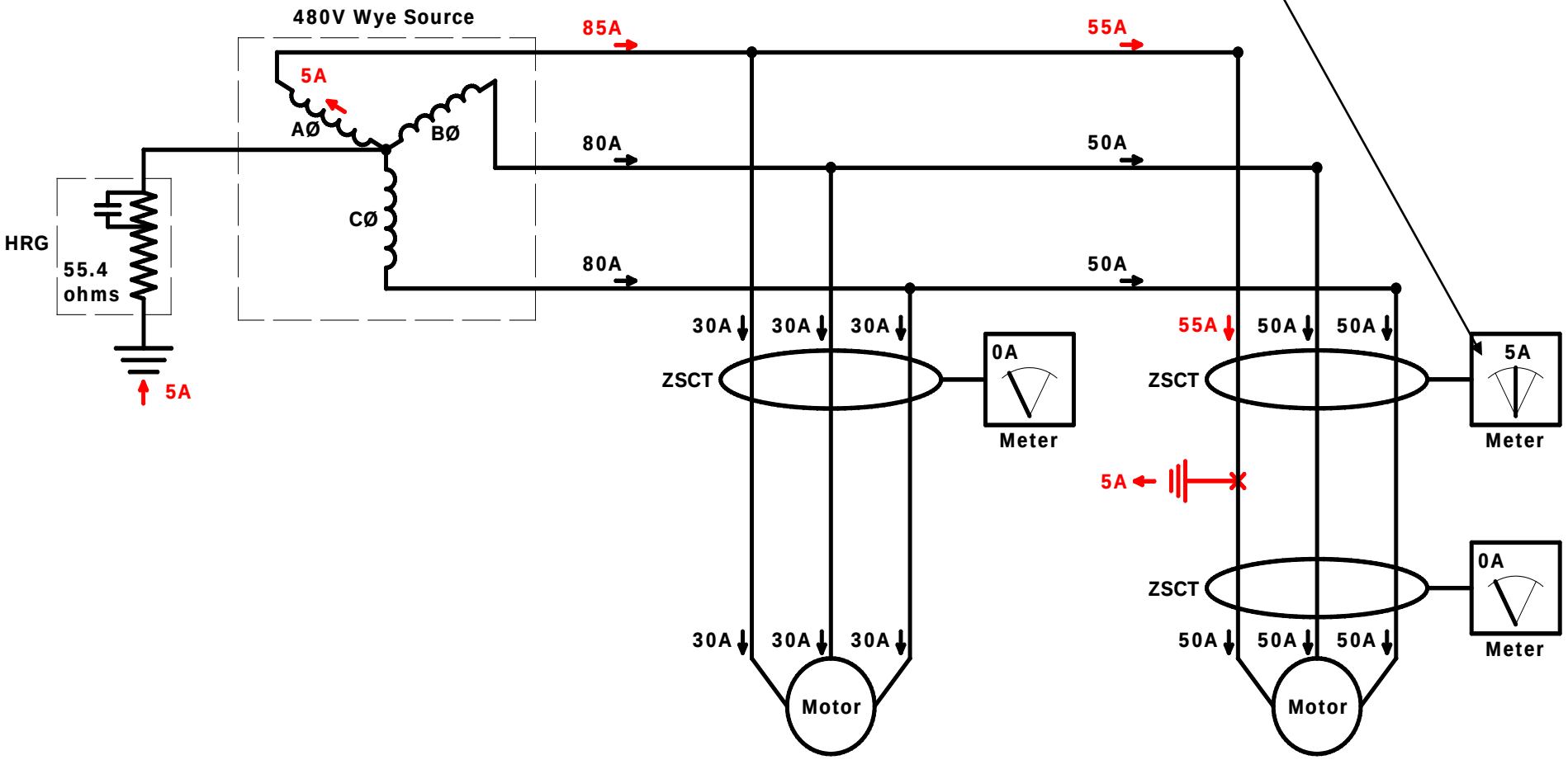
- Picture of old style Fault Location Process



High Resistance Grounding

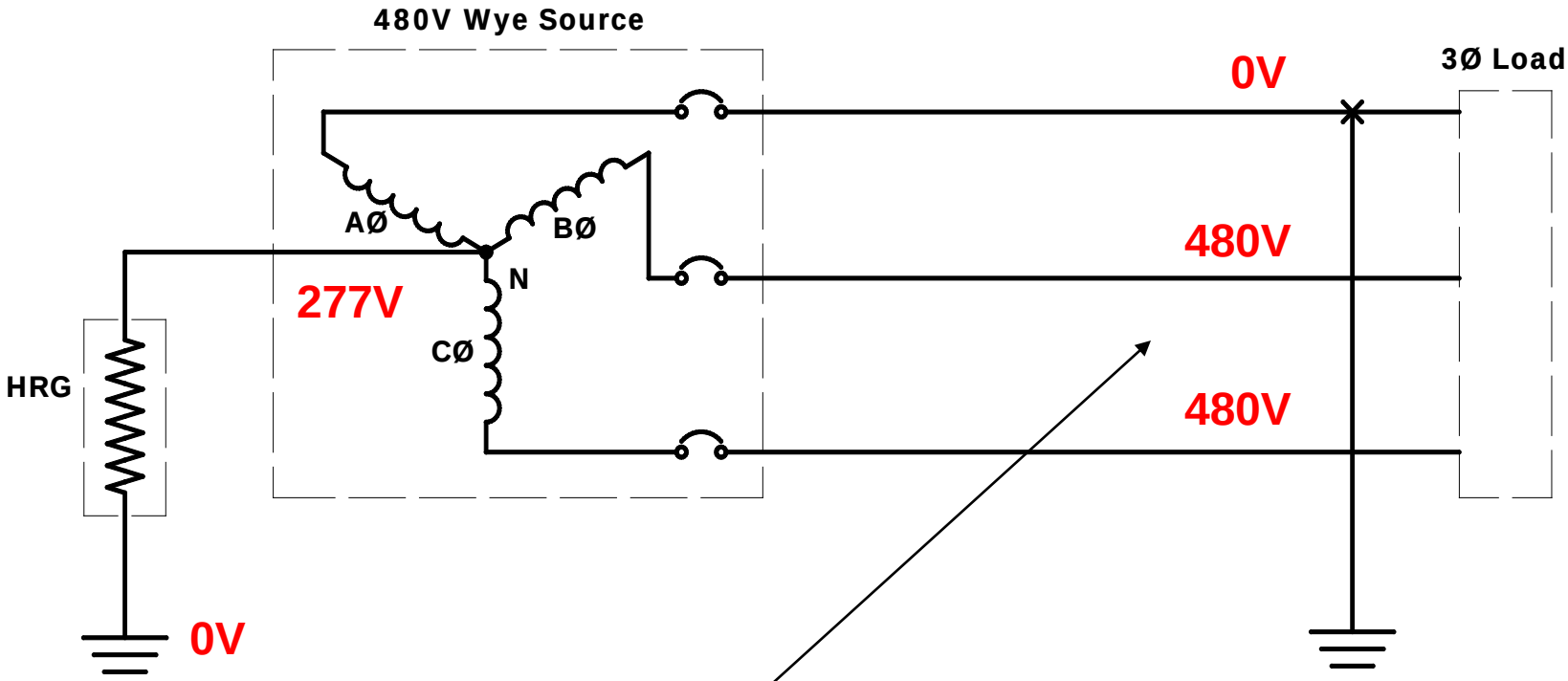
- Method to quickly locate ground faults.

Meter reading will alternate from 5A to 10A every 2 seconds.



Elevated Voltage Hazard

- Properly rated equipment prevents Hazards.



Cables, TVSSs, VFDs, etc. and other equipment must be rated for elevated voltages (Ungrounded Systems).

15kV System Design

- 400A Resistance grounded wye connected system
- Greatly reduce fault energy for ground faults
- Table assumes 25MVA 7% transformer with .3 sec clearing time

	watt sec	Cal/CM^2
Solid grounded 15kA fault	107,000 MW-sec	151
Resistance grounded 400A Limit	2.8MW-sec	4

Transformer Secondary Connection

- Bus Duct
  - No low impedance bus duct (Sandwich Bus)
  - Segregated Phase Bus Duct
  - Iso-phase
  - Cable bus
- Design for phase to ground faults
- Insulated terminations

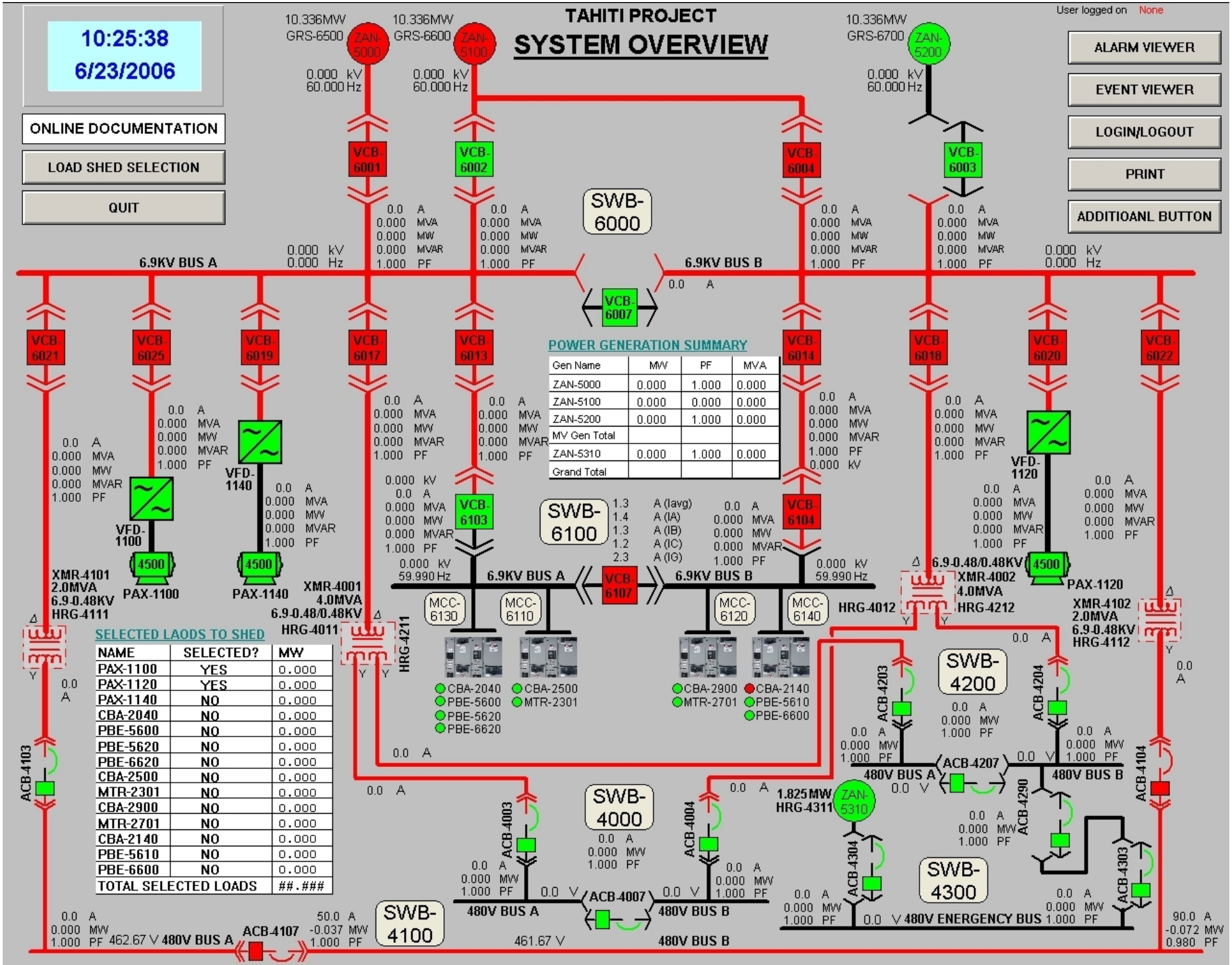
Smart Substation

Smart Switchgear System

- Operating Distance / PPE
- Substation Monitoring and Notification
- History and Trending
- Diagnostics and Troubleshooting
- Documentation
- Future Technologies

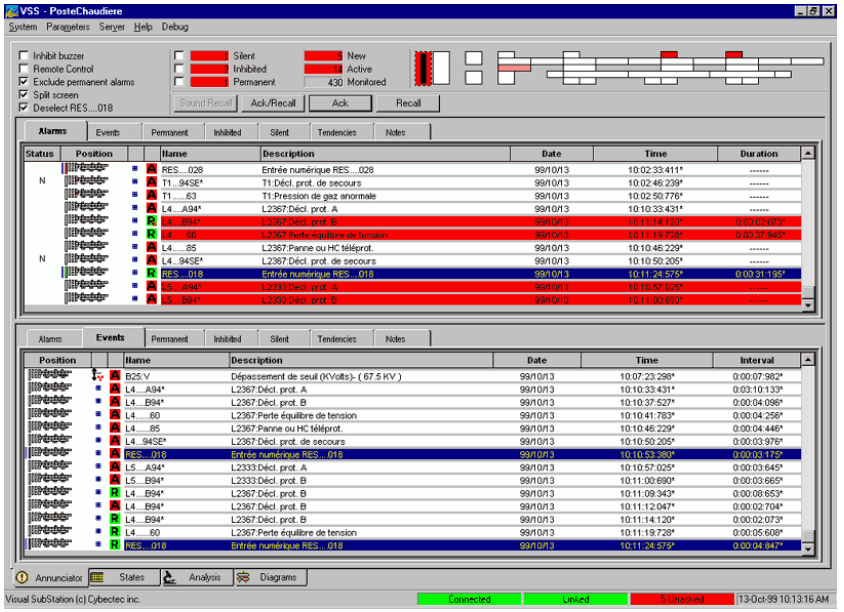
Improper Operation

- Interlocks Standard and Optional
- On hand documentation
- Factory training certifying the individual as qualified for the equipment
- Smart substation


TAHITI PROJECT
SYSTEM OVERVIEW
User logged on None
10:25:38
6/23/2006
ONLINE DOCUMENTATION
LOAD SHED SELECTION
QUIT
ALARM VIEWER
EVENT VIEWER
LOGIN/LOGOUT
PRINT
ADDITIOANL BUTTON
10.336MW GRS-6500 ZAN-5000
10.336MW GRS-6600 ZAN-5100
10.336MW GRS-6700 ZAN-5200
VCB-6001
VCB-6002
VCB-6004
VCB-6003
SWB-6000
6.9KV BUS A
6.9KV BUS B
VCB-6007
VCB-6021
VCB-6025
VCB-6019
VCB-6017
VCB-6013
VCB-6014
VCB-6018
VCB-6020
VCB-6022
POWER GENERATION SUMMARY
Gen Name | MW | PF | MVA
ZAN-5000 | 0.000 | 1.000 | 0.000
ZAN-5100 | 0.000 | 0.000 | 0.000
ZAN-5200 | 0.000 | 1.000 | 0.000
MV Gen Total
ZAN-5310 | 0.000 | 1.000 | 0.000
Grand Total
VFD-1100
VFD-1140
VFD-1120
PAX-1100
PAX-1140
PAX-1120
4500
XMR-4101 2.0MVA 6.9-0.48KV HRG-4111
XMR-4001 4.0MVA 6.9-0.48/0.48KV HRG-4011
HRG-4211
VCB-6103
SWB-6100
VCB-6104
VCB-6107
1.3 A (Iavg)
1.4 A (IA)
1.3 A (IB)
1.2 A (IC)
2.3 A (IG)
59.990 Hz
MCC-6130
MCC-6110
MCC-6120
MCC-6140
HRG-4012
XMR-4002 4.0MVA 6.9-0.48/0.48KV HRG-4212
XMR-4102 2.0MVA 6.9-0.48KV HRG-4112
SELECTED LAODS TO SHED
NAME | SELECTED? | MW
PAX-1100 | YES | 0.000
PAX-1120 | YES | 0.000
PAX-1140 | NO | 0.000
CBA-2040 | NO | 0.000
PBE-5600 | NO | 0.000
PBE-5620 | NO | 0.000
PBE-6620 | NO | 0.000
CBA-2500 | NO | 0.000
MTR-2301 | NO | 0.000
CBA-2900 | NO | 0.000
MTR-2701 | NO | 0.000
CBA-2140 | NO | 0.000
PBE-5610 | NO | 0.000
PBE-6600 | NO | 0.000
TOTAL SELECTED LOADS | ##.###
CBA-2040 PBE-5600 PBE-5620 PBE-6620
CBA-2500 MTR-2301
CBA-2900 MTR-2701
CBA-2140 PBE-5610 PBE-6600
ACB-4103
ACB-4203
ACB-4204
SWB-4200
480V BUS A
480V BUS B
ACB-4207
ACB-4104
ACB-4290
1.825MW HRG-4311 ZAN-5310
ACB-4304
SWB-4300
480V ENERGENCY BUS
ACB-4303
ACB-4003
ACB-4004
SWB-4000
ACB-4007
ACB-4107
SWB-4100
462.67 V
461.67 V

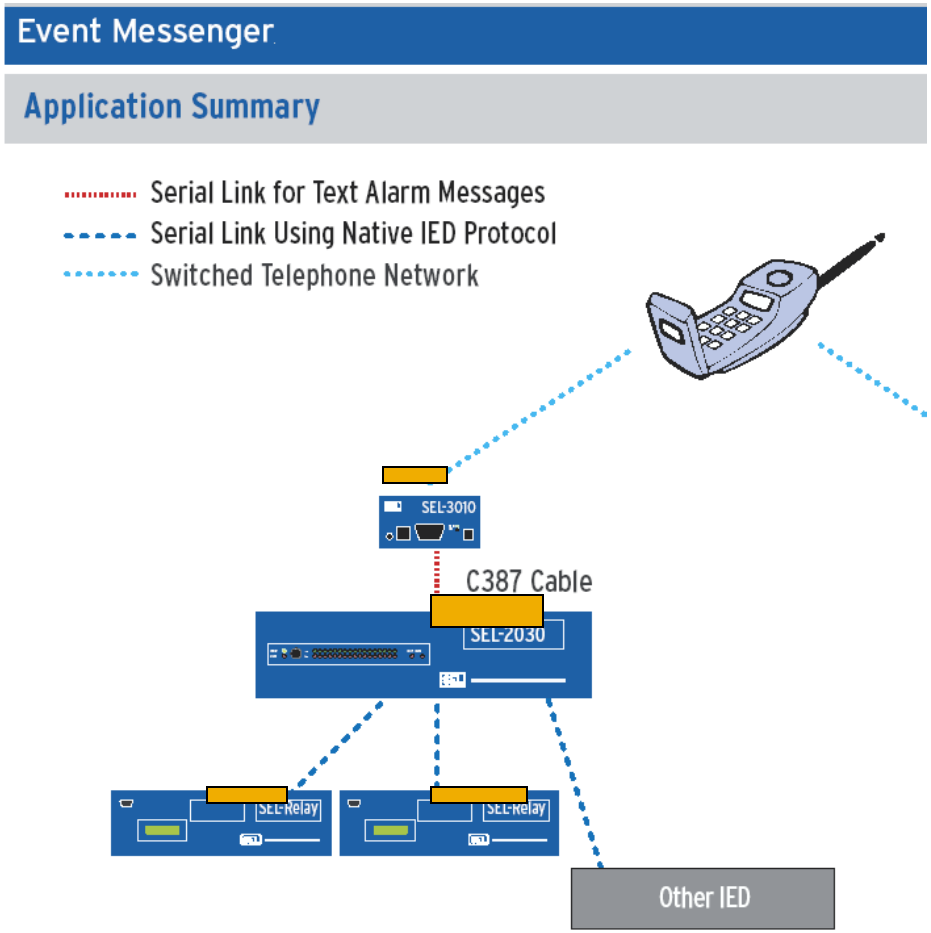
Alarm History

- Xfmr Fault
- Loss of Control Power
- Fire Alarm
- Ground Fault alarm on HRG
- Upstream breaker opened
- Condensate heaters



Notification

- Alarm window with common alarm to control house
- Email
- Pager
- Cell Phone

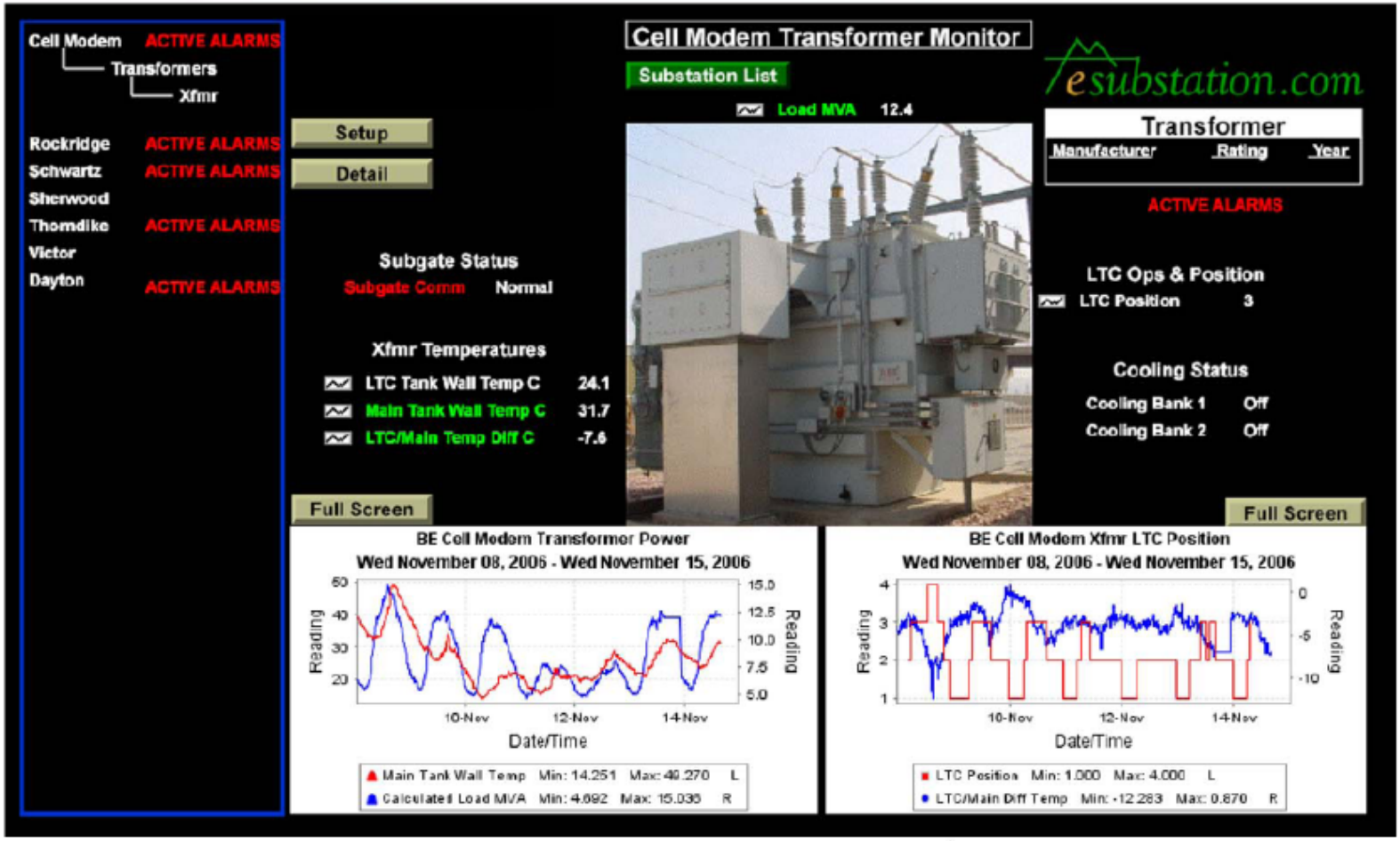


Substation Monitoring

- HVAC failed
- Xfmr
  - Blanket
  - Purge
  - Temp
  - Fans
- Relay Failed
- Circuit breaker trip coil monitor

COOPER Power Systems
Energy Automation Solutions

eSubstation Overview Screenshot



CANNON TECHNOLOGIES
Powered by Yukon

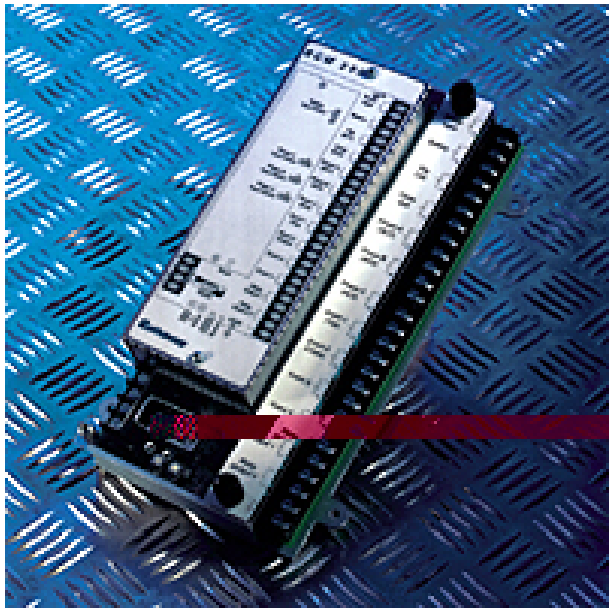
cybectec

On-Line Diagnostics

- Xfmr, gas and water Analysis
  - Oil Oxidation
  - Water
  - Over heating
  - Turn to turn arcing
- Battery System
  - Cell voltage
  - Plate decomposition

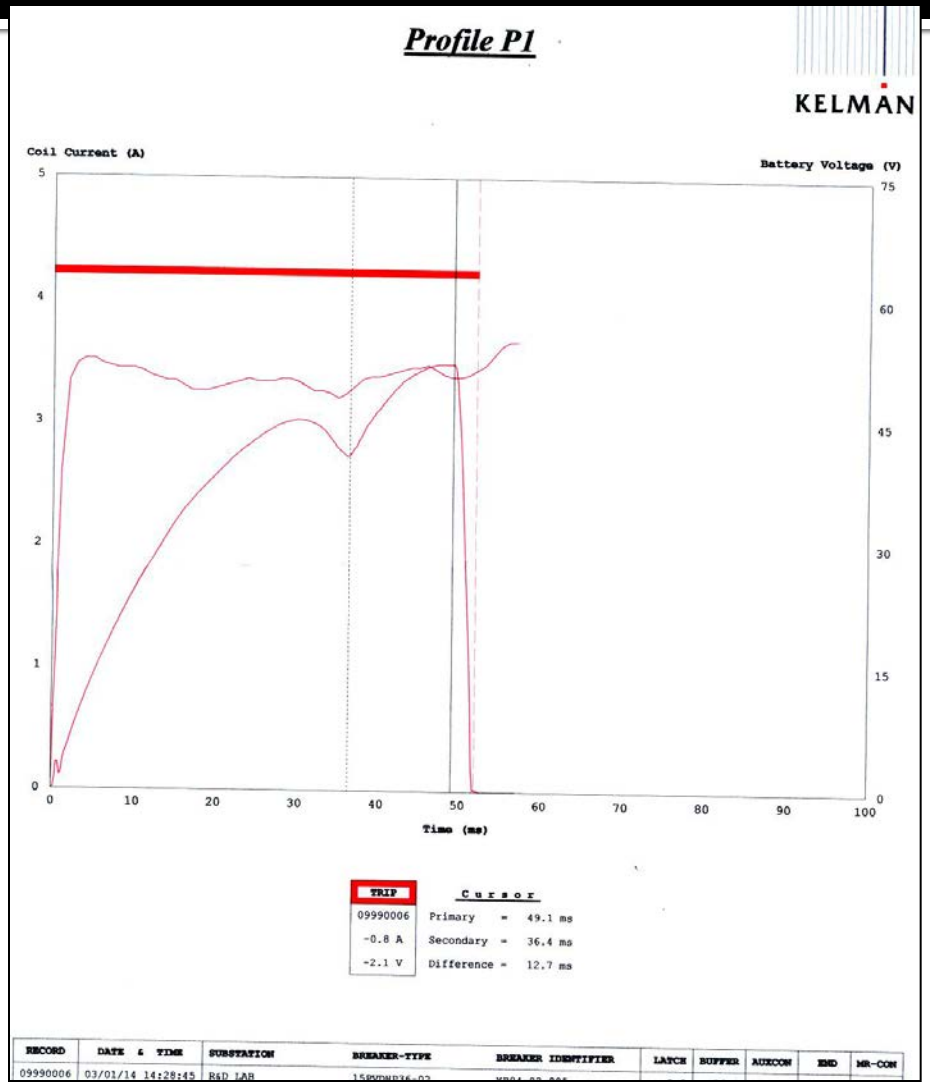
What are the primary reliability interests

- Protection system
- Battery System
- Tripping Circuit
- Breaker & Switchgear Integrity

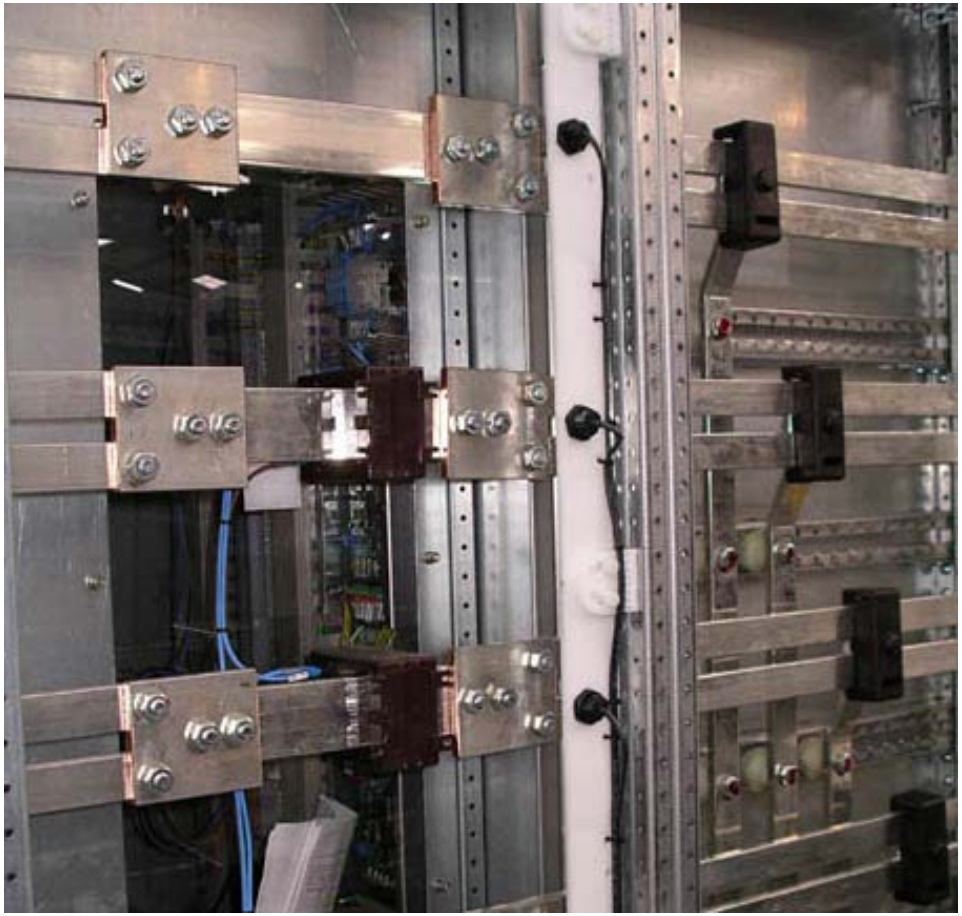


On-Line Diagnostics

- Breaker Timing
  - First time operation
  - Latch operation
  - Speed
- Breaker Trip and close Coil
  - Current vs. Voltage



Continuous Thermal Monitoring



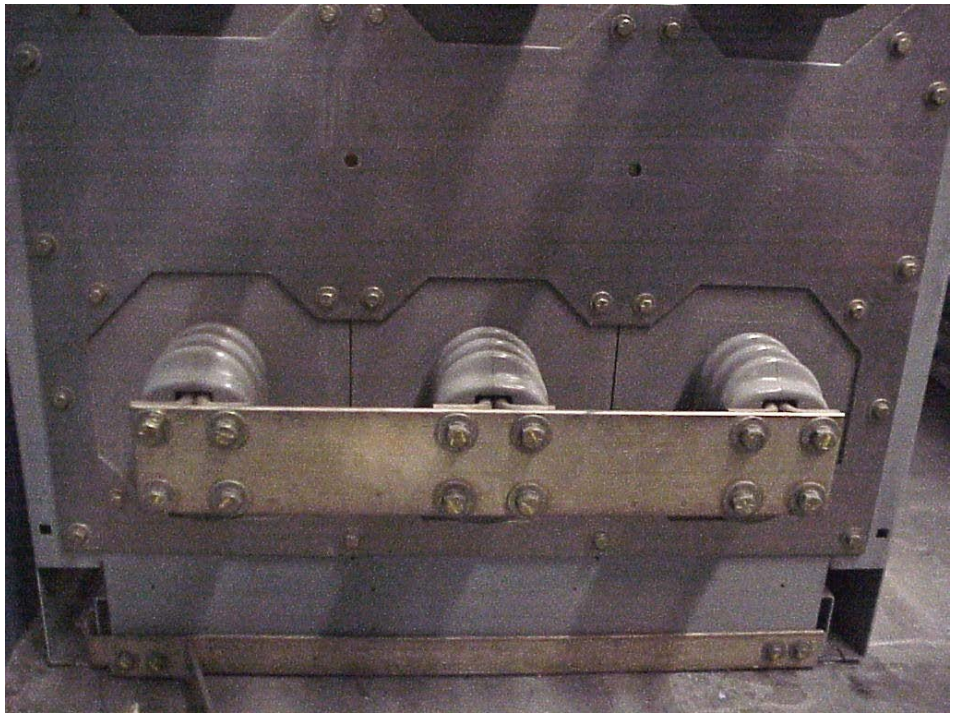
Documentation

- System one lines
  - Auto cad files
- Equipment drawings
- Breaker data
- Instruction Bulletin
- Device "cut sheets"

Arcing Faults

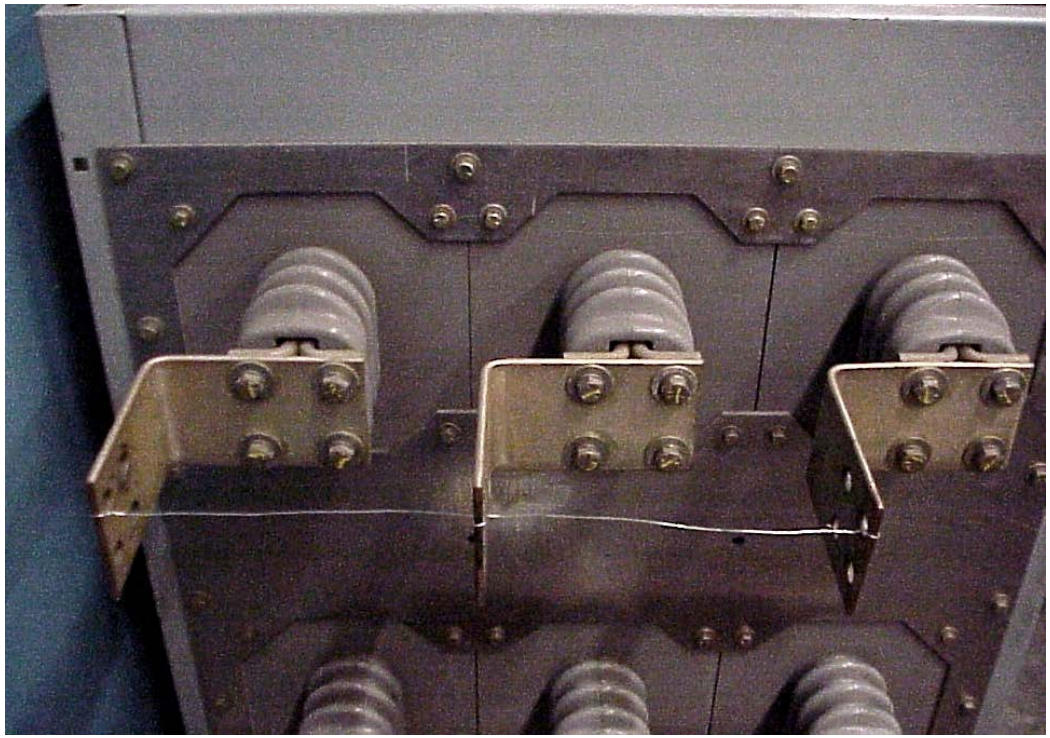
Bolted Fault vs. Arcing Fault in Medium-Voltage Switchgear

- **Bolted Faults**
  - Current I^2t
  - Mechanical forces
- **Testing**
  - Interrupting capability
  - Thermal capacity of bus
  - Mechanical bracing of bus



Bolted Fault vs. Arcing Fault in Medium-Voltage Switchgear

- **Arc Faults**
  - Mechanical forces and Current I^2t
  - Heating and burning of conductors and enclosure
  - Radiation
  - Rapid overpressure of equipment and surroundings



Arc Resistant is the equivalent to a 70E Zone 0 at 3.9" due to test recordings of 2 cal/cm

Zone 1 as minimum dress for all electrical work

- Leather gloves
- Long sleeve FRC clothing (shirt and pants)
- Approved eye protection

Arc Faults

Cell before the fault

Fault the result of racking in a 5kV 40 yr old breaker with one pole closed

Feeder Breaker where fault began Cell 3

Incoming breaker Cell 1

Next cell over Cell 2

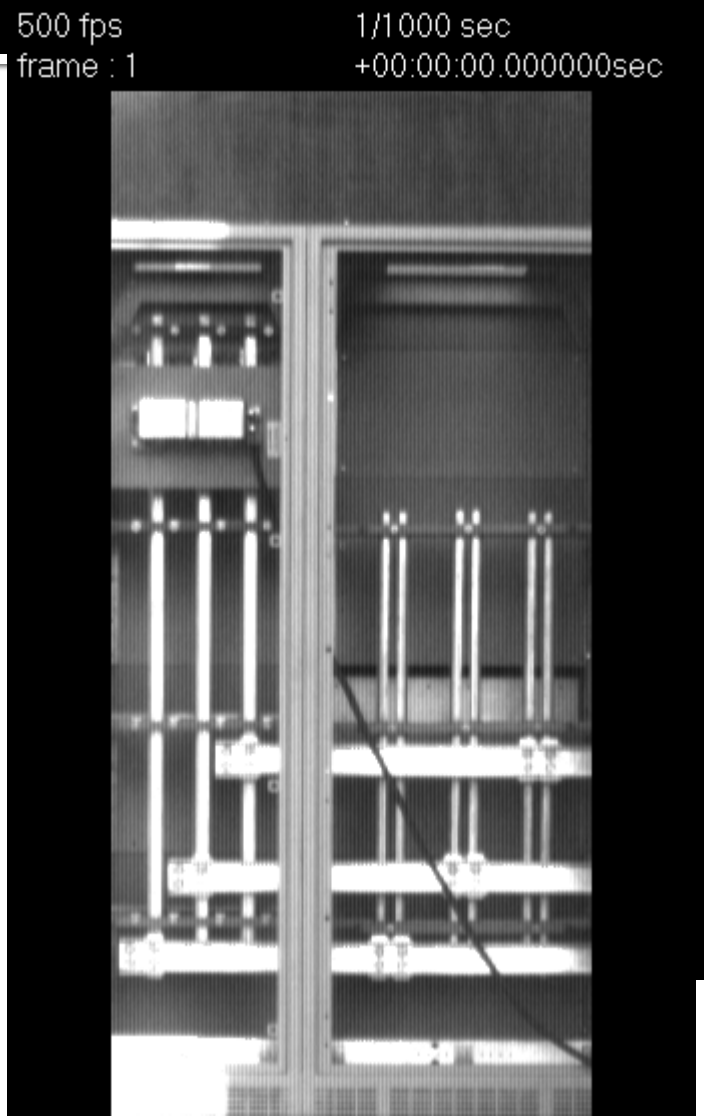
Cell 4

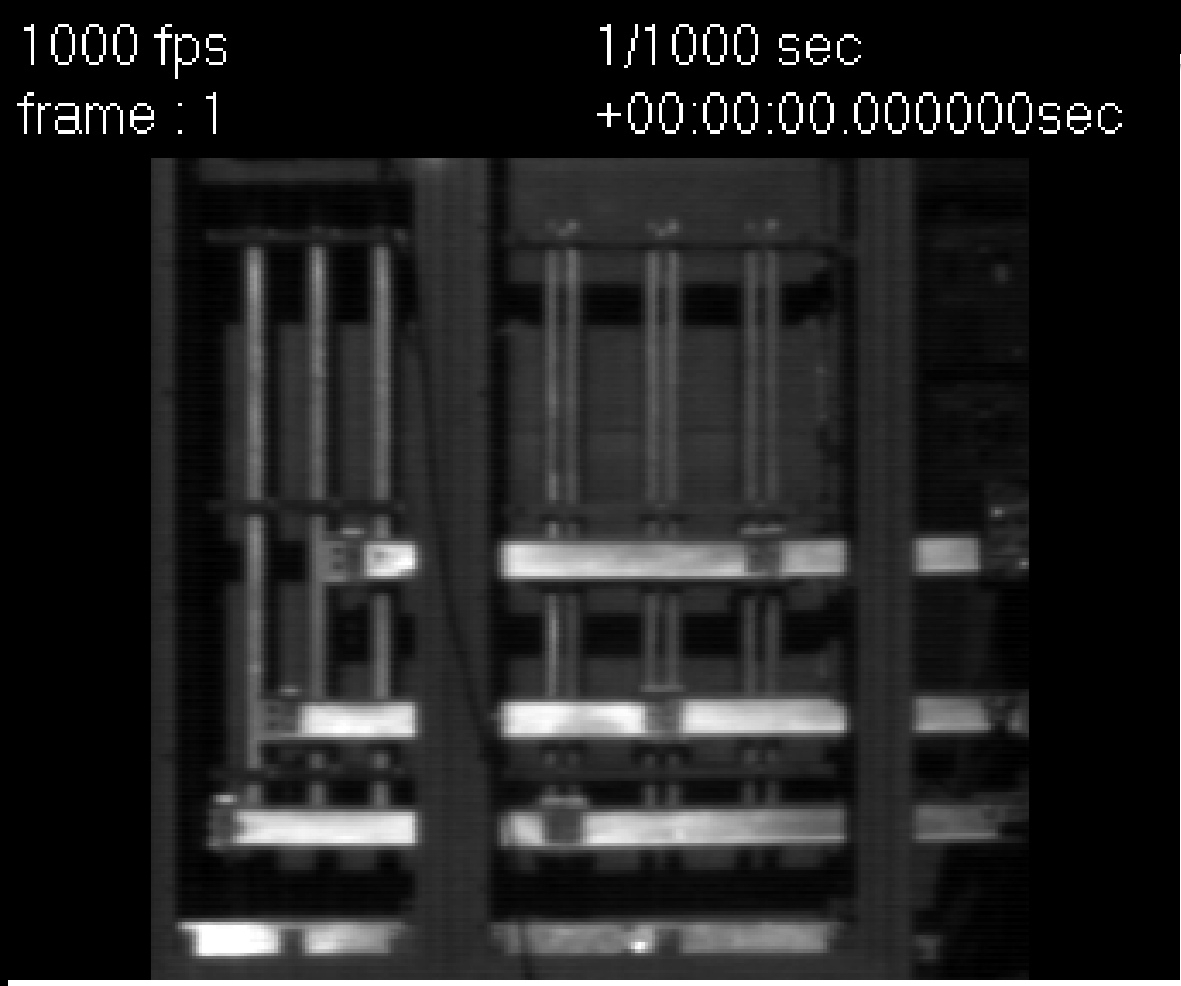
Arcing Faults

Christmas 2003

Bus bracing failure

Short Circuit Short time





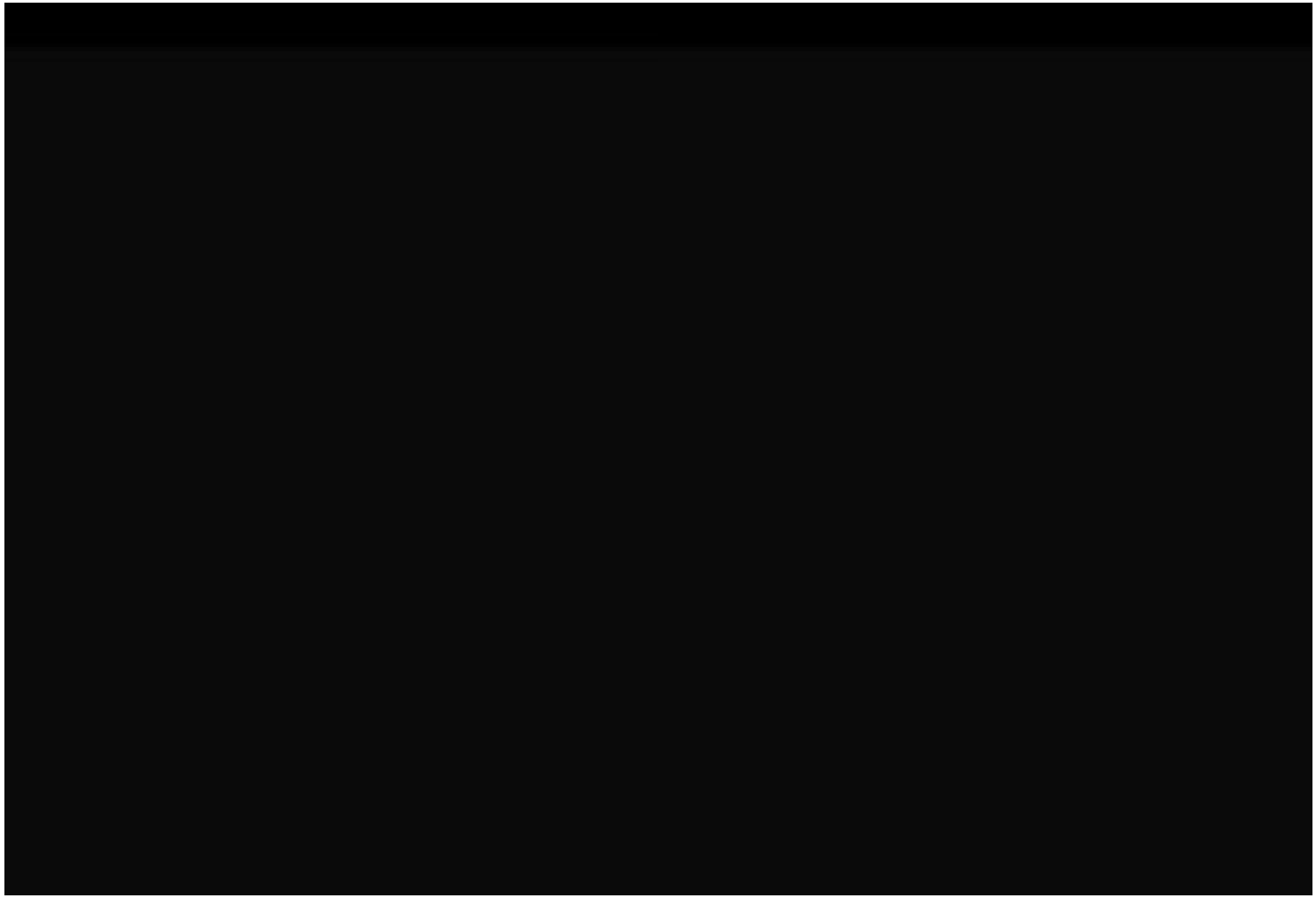
Failed 50kA 5kV available fault current 0.5sec

Heat, Pressure, Smoke and Shrapnel
15kV, 50kA

Hazardous Effects of an Arcing Fault

- 13.8 kV system
- Side view bus compartment fault
- 38 kA symmetrical fault
- Duration of 1 second

Effects of the Pressure Wave notice the door



Accessibility Type

EEMAC

No Building Effect

Type A - Front only

Type B - Front, back and sides

Type C - Front, back and sides and between the compartments

Note: bus compartment allowed to break into the bus compartment of an adjacent feeder cell

ANSI C37.20.7

Building Effect Considered

Type 1 - Front only

Type 2 - Front, back and sides

Type b – Instrument compartment protection

Type c - Front, back and sides and between the compartments

Note: bus compartment allowed to break into the bus compartment of an adjacent feeder cell

Test Assessment

- Doors & covers do not open.
- Parts, which may cause hazard, do not fly off.
- No burn through accessible external parts
- Heat indicators do not ignite from escaping gas
- All Earthing connections must remain effective.

Free Standing Plenum

- Number of exhaust ducts
- Clearance issues
- TOS
  - 124" for 95" high gear
  - 133" for 105" high gear

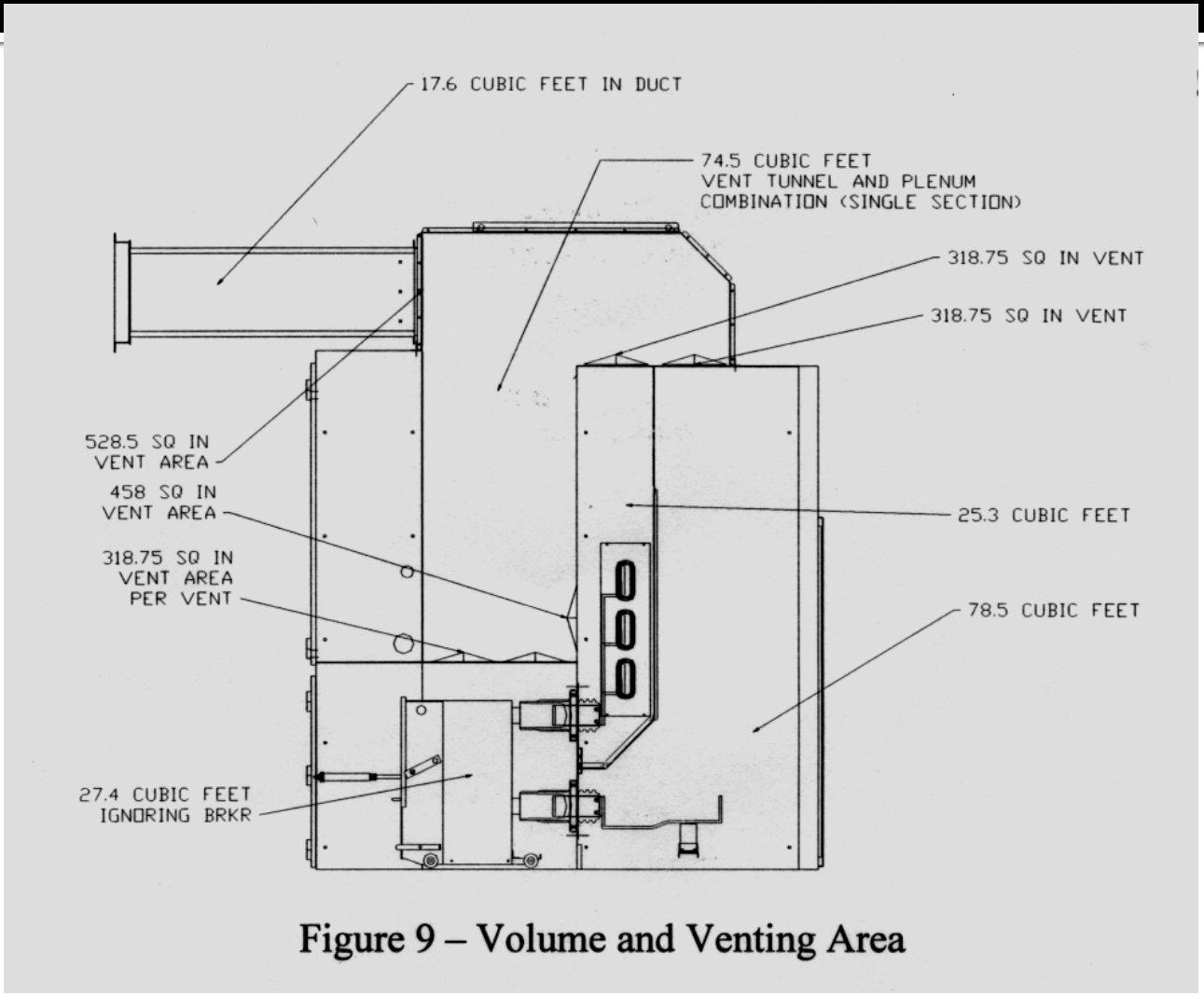


Figure 9 – Volume and Venting Area

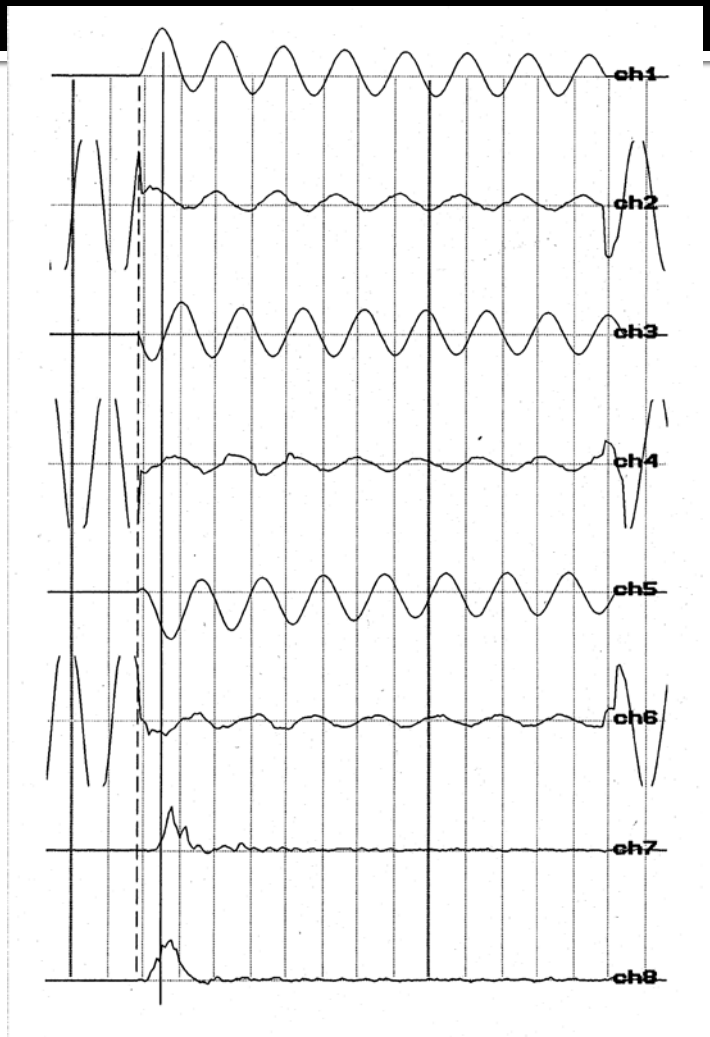
Test Sample

PT Rollout for Arc Resistant Switchgear

Pressure Transducer (front)

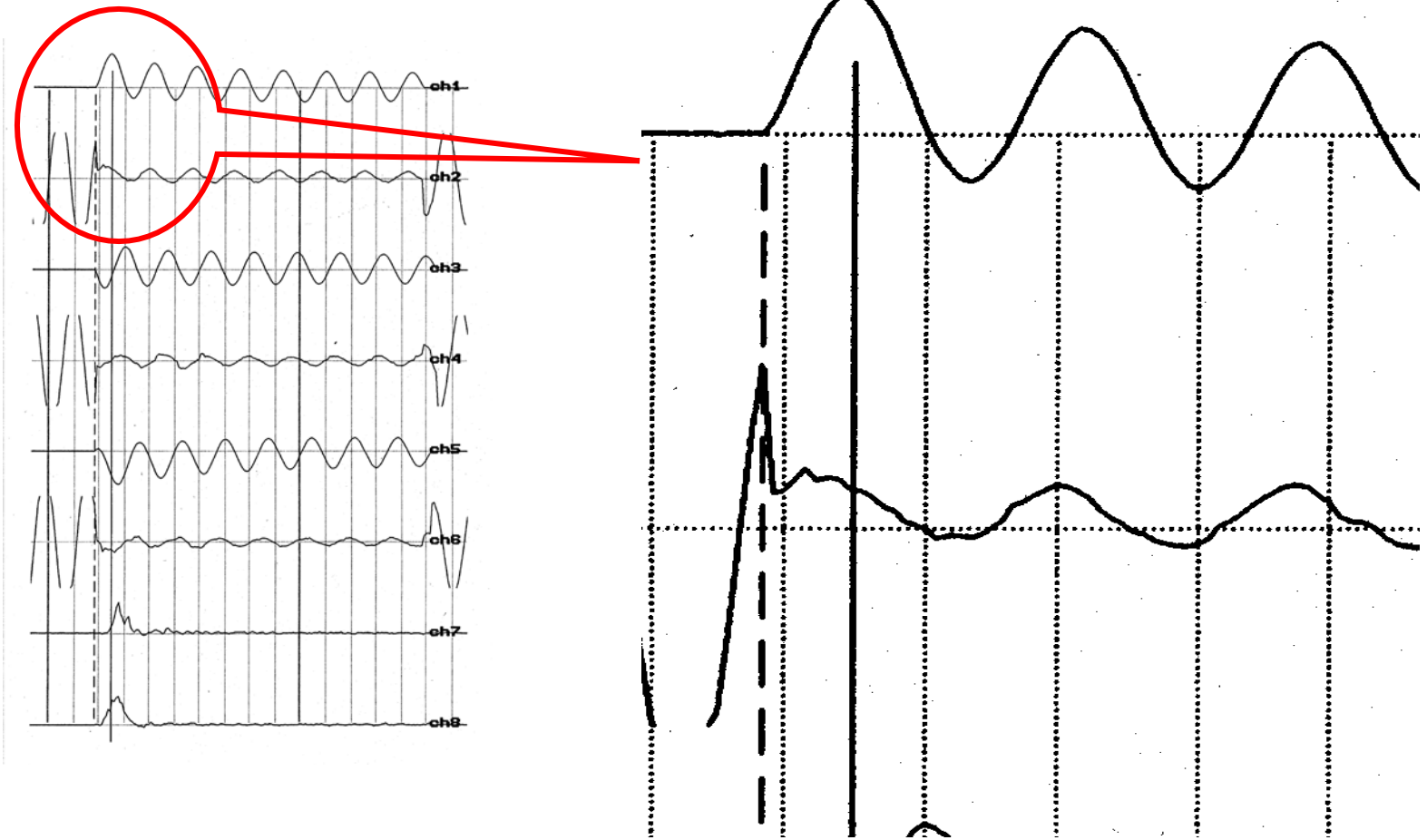
Rollout Drawer

Test Results

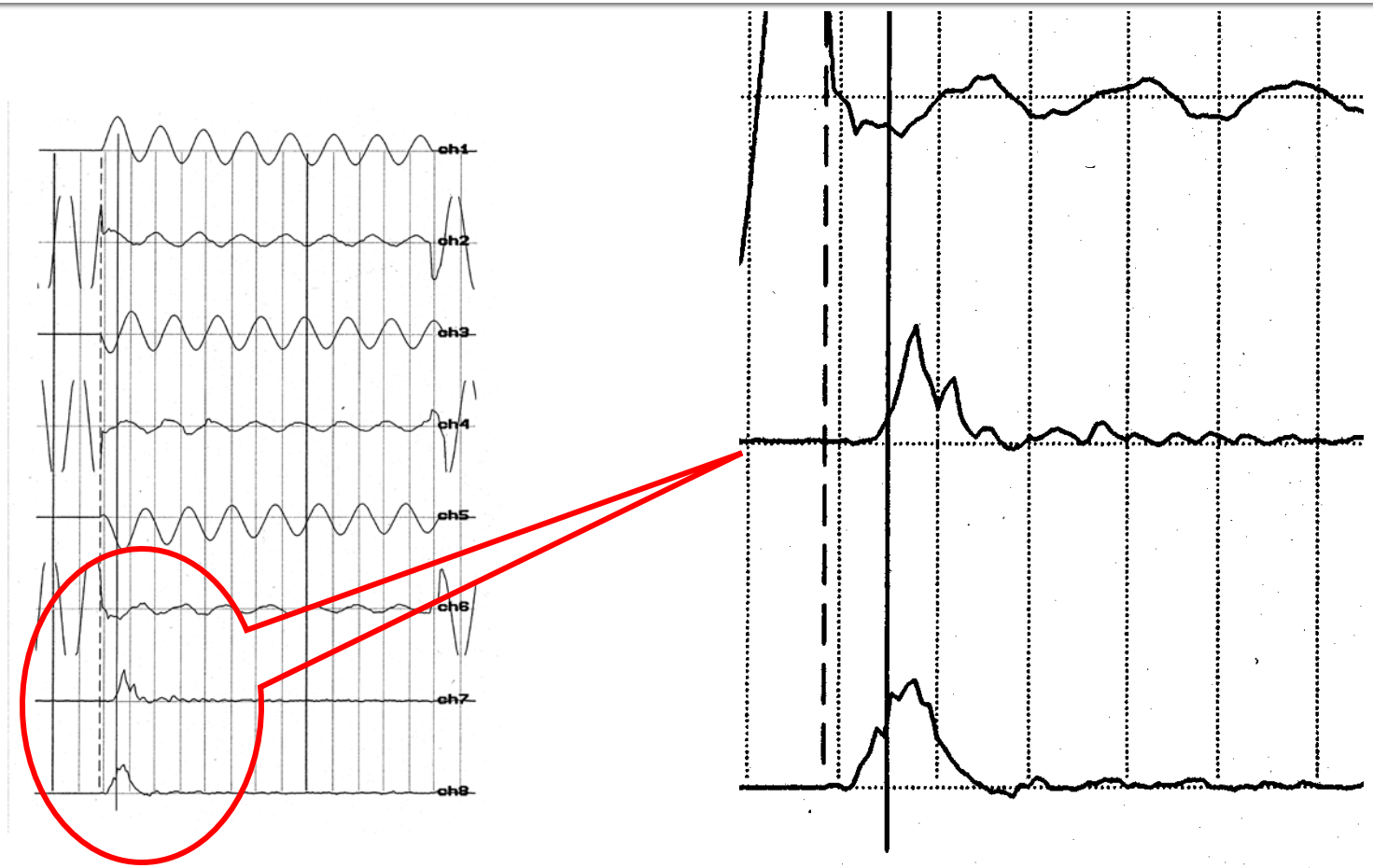


- Ch1 - A phase current 119kA peak
- Ch2 - A phase voltage 620V arc voltage
- Ch3 - B phase current
- Ch4 - B phase voltage
- Ch5 - C phase current
- Ch6 - C phase voltage
- Ch7 - Pressure at front 37.6psi @ 9.7ms
- Ch8 - Pressure at rear 38.0psi @ 9.3ms

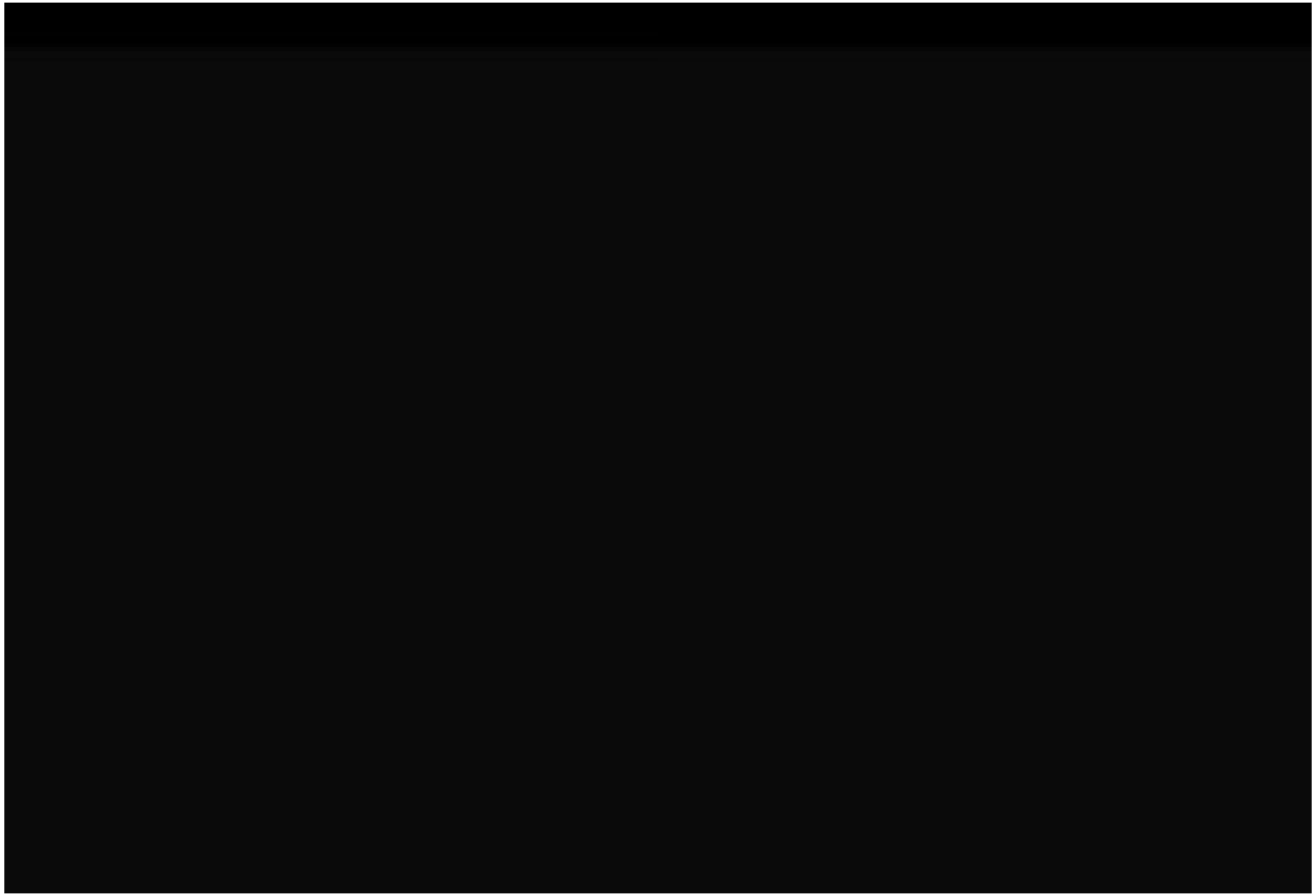
Test Data (cont)



Test Data (cont)



What Is An Arcing Fault ?



Hazards of an Arcing Fault

- Direct/indirect exposure to the arc flash
- Mechanical stress from pressure waves
- Thermal stress from the radiated heat
- Potential contact with energized parts
- Release of toxic gases
- Airborne debris

Inside of Arc Resitant after .5sec shot

Incoming cable connection

Arc Resistant Switchgear

- Protect the individual during
  - Racking operation
  - Open and Close
  - PT's and Cpt's on and off the bus
  - Troubleshooting control problems
  - Infrared Inspection with approved view ports
  - Operator error
    -
  - All hazard of the fault not just heat

63kA 3000Amp

Closed Door Racking

Arc Resistant Switchgear

- Single Throw handle
- Door to racking position interlock

Arc Resistant Switchgear

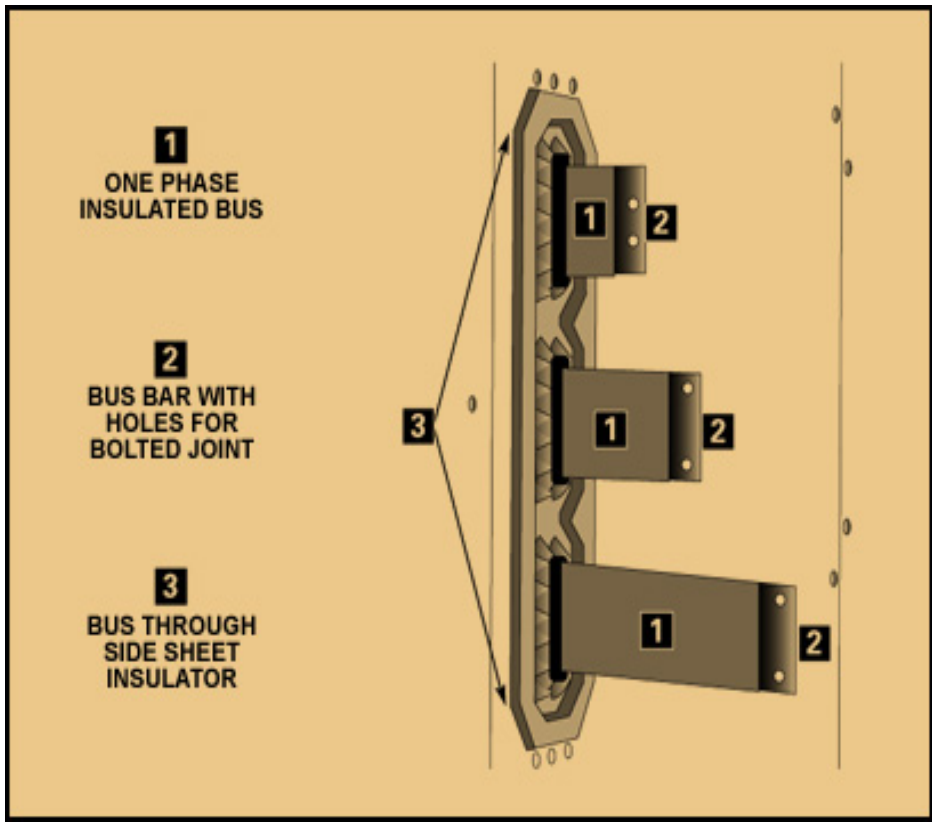
- Internal lights
- View windows
- Manual trip

Back View With Plenum

Free Standing Swgr

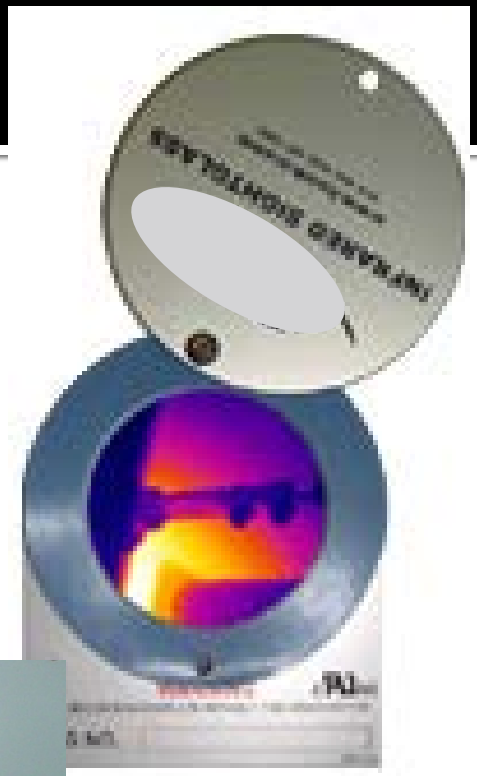
Switchgear (Insulation)

- Epoxy Coated Bus Bar Insulation
- Epoxy insulation in lieu of glastic stand off
- High potential testing for shipping damage (*AC vs. DC*)
- Old Norel Systems

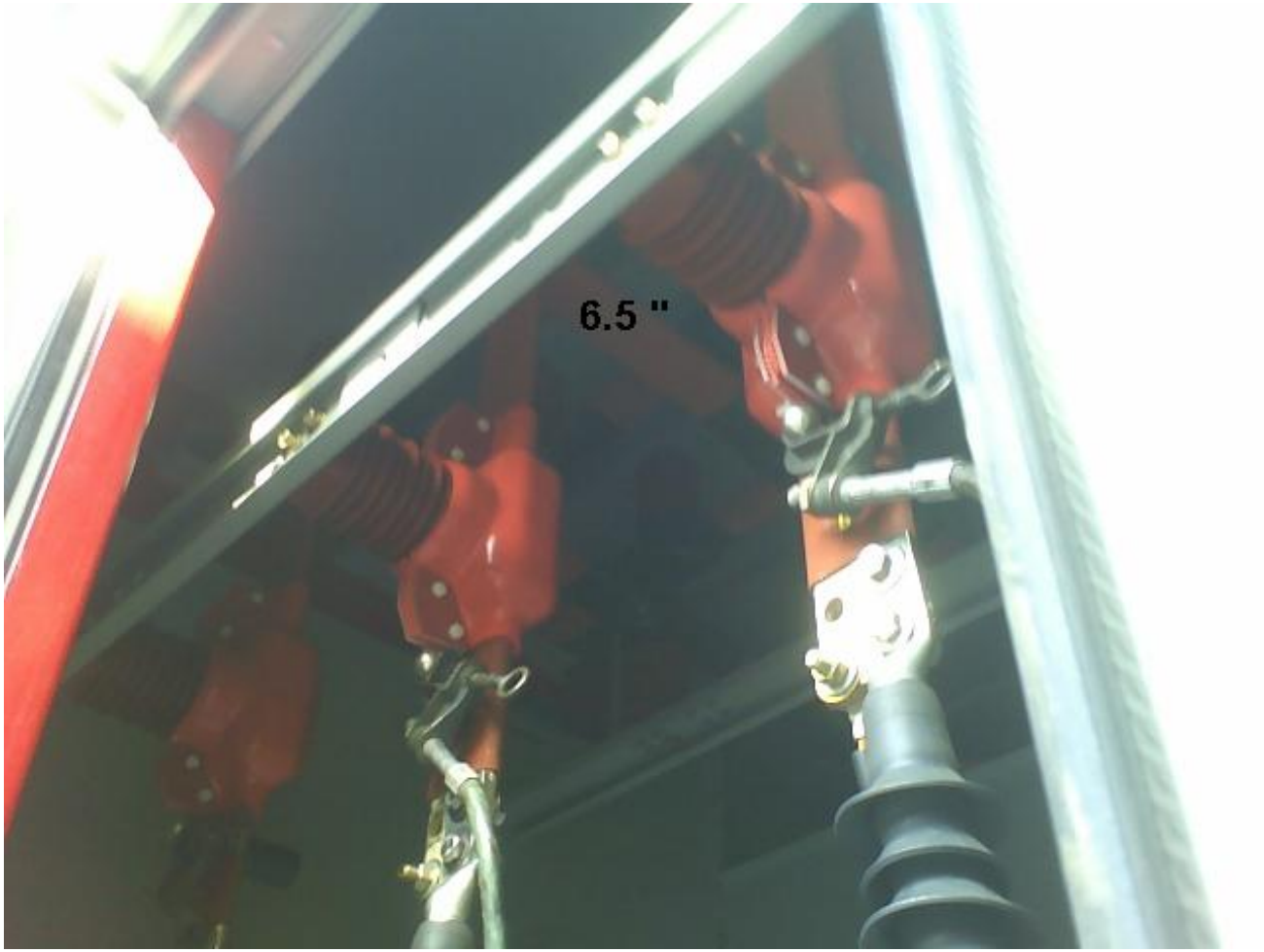


Infrared Ports

- Monitoring without exposure
- Fixed mount for inaccessible high current density location



Ground Studs In cable compartment



MV Swgr (safety grounds)

- Safety grounding method
  - Manual Ground & Test device
  - Electrical Ground Device
  - Ground switch
  - Grounding pawls rated for the service

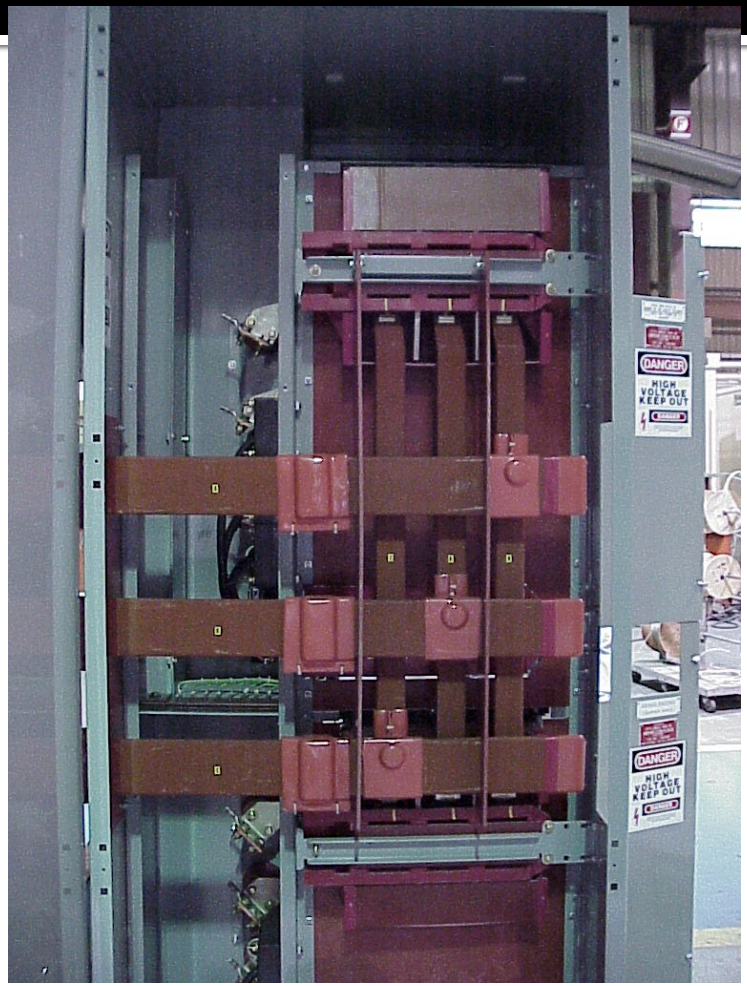
5 KV Switchgear And MCC

Medium Voltage Motor Control

- Two Hole Lugs
- Insulated Lugs
- Ground studs

Medium Voltage Motor Control

- MVMCC has switchgear short circuit rated bus
- Additional Barriers and Insulation
- Posted approved voltage measuring method

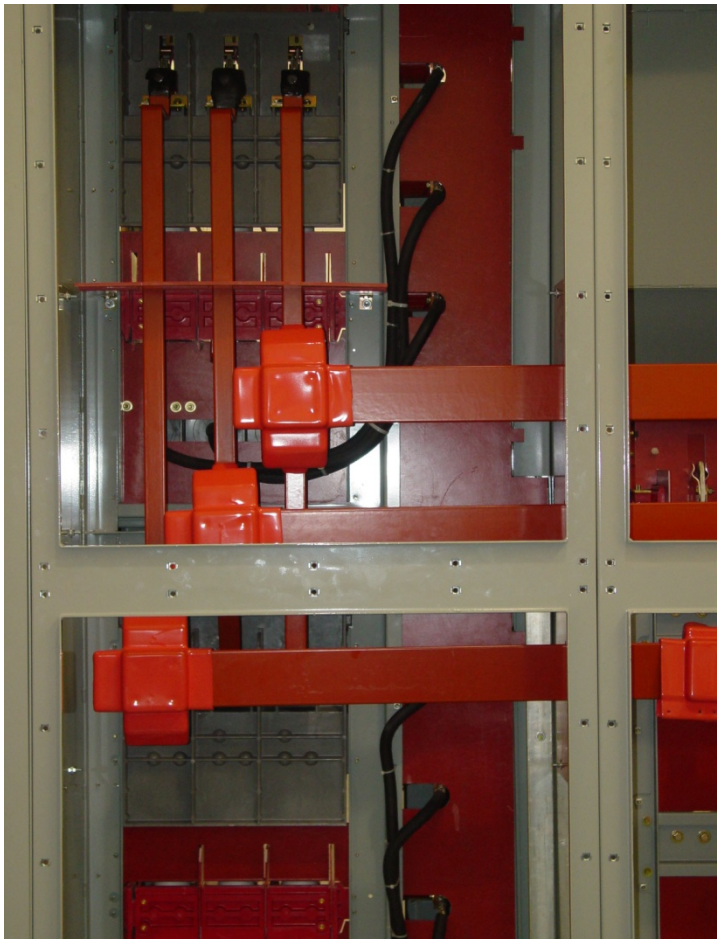


MVMCC AR

- Separate controls compartment
- View windows
- Main bus short time rating

MVMCC Arc Resistant

Main Bus Configuration

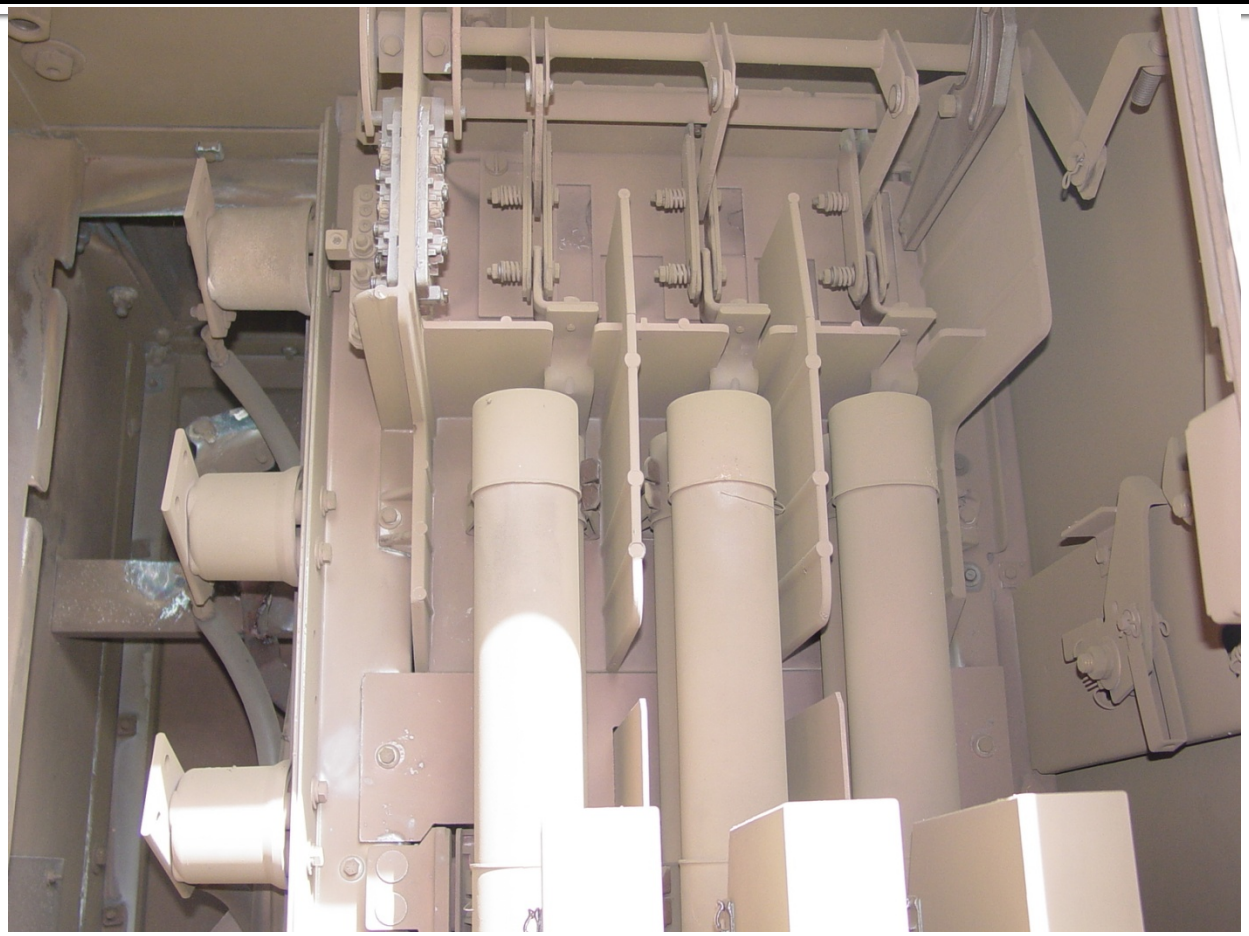


Fault location

- Line side of fuses

Equipment Damage

- Top of fuse barrels



Adjacent Cell

Arc Fault Test 50kA 5kV MCC

4160Voltage Measurement Fault

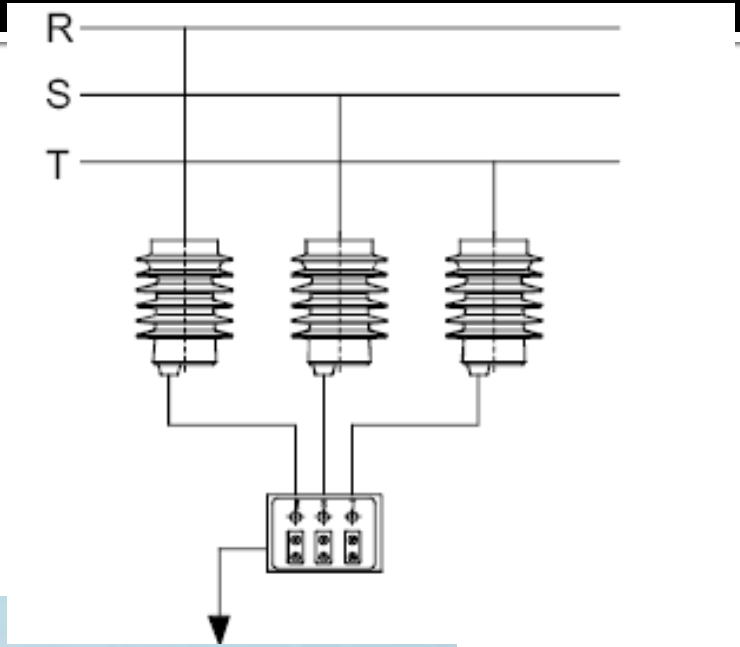
- Results of using a 1000 V meter on 4160 V

4160 Voltage measurement fault

- PPE of the tech doing the measurement

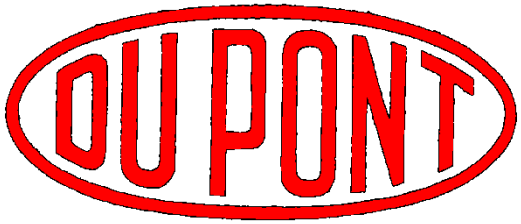
Fixed voltage measurement

- Non Contact voltage confirmation for MV
- MVMCC solution for de-energized circuit



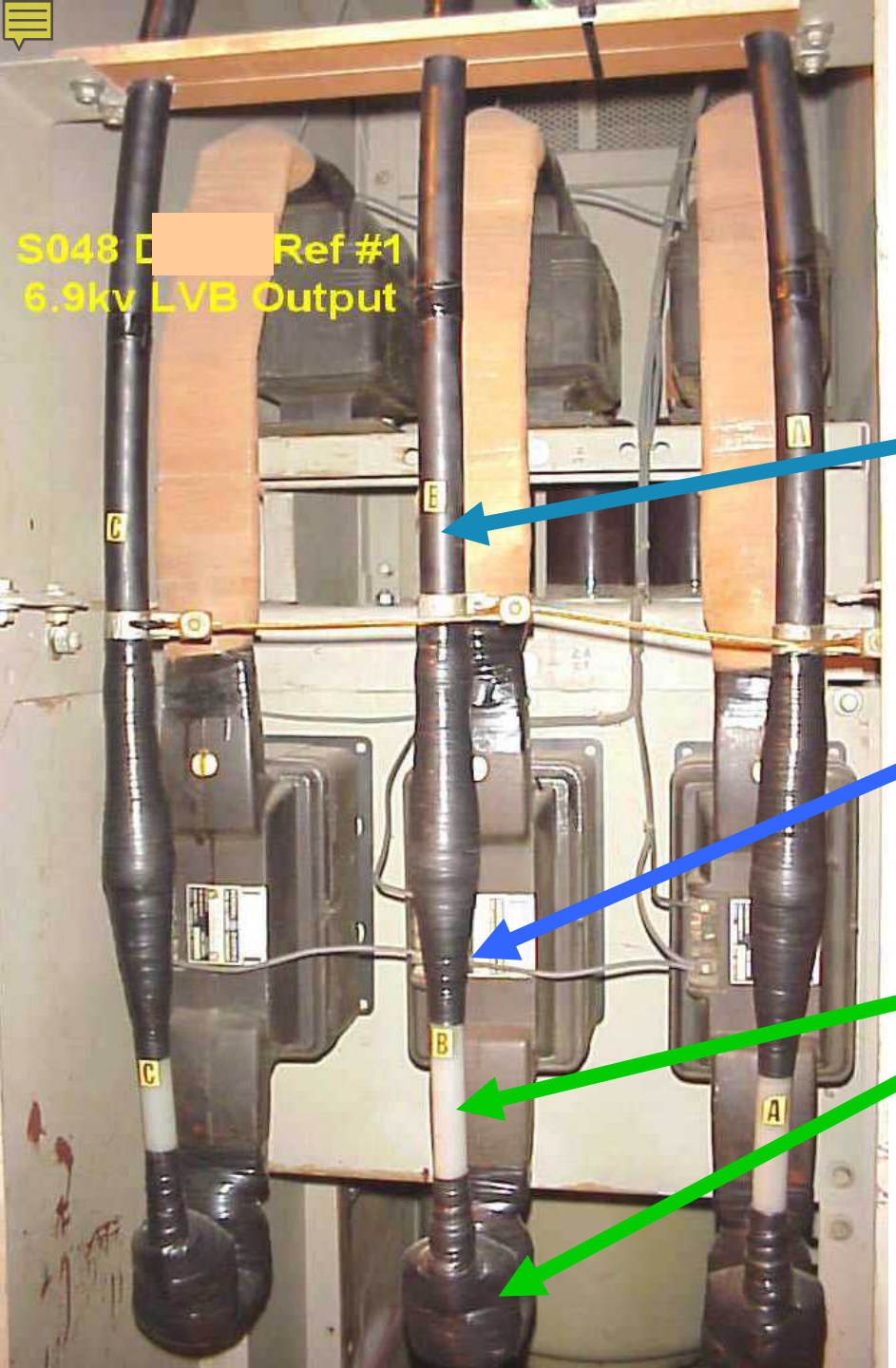
"Test Before Touch" What Does This Mean to You?

Ken Crawford, P.E. - DuPont
Kent Haggerty, P.E. - DuPont



Considerations in Testing Medium Voltage Systems

- Proximity Testers Often Preferred Due to Strong Electric Fields
  - Direct Contact Not Required
  - Only One Probing Stick Needed
  - Can Test Taped Connections
- Shielded Conductors Cannot Be Tested Except at Terminal Connections
  - Spiking Tool May Be Necessary to Verify Shielded Conductors Are De-energized



Medium Voltage Shielded Cables Require Special Attention

Shielded Cable - Proximity Tester Will Not Indicate

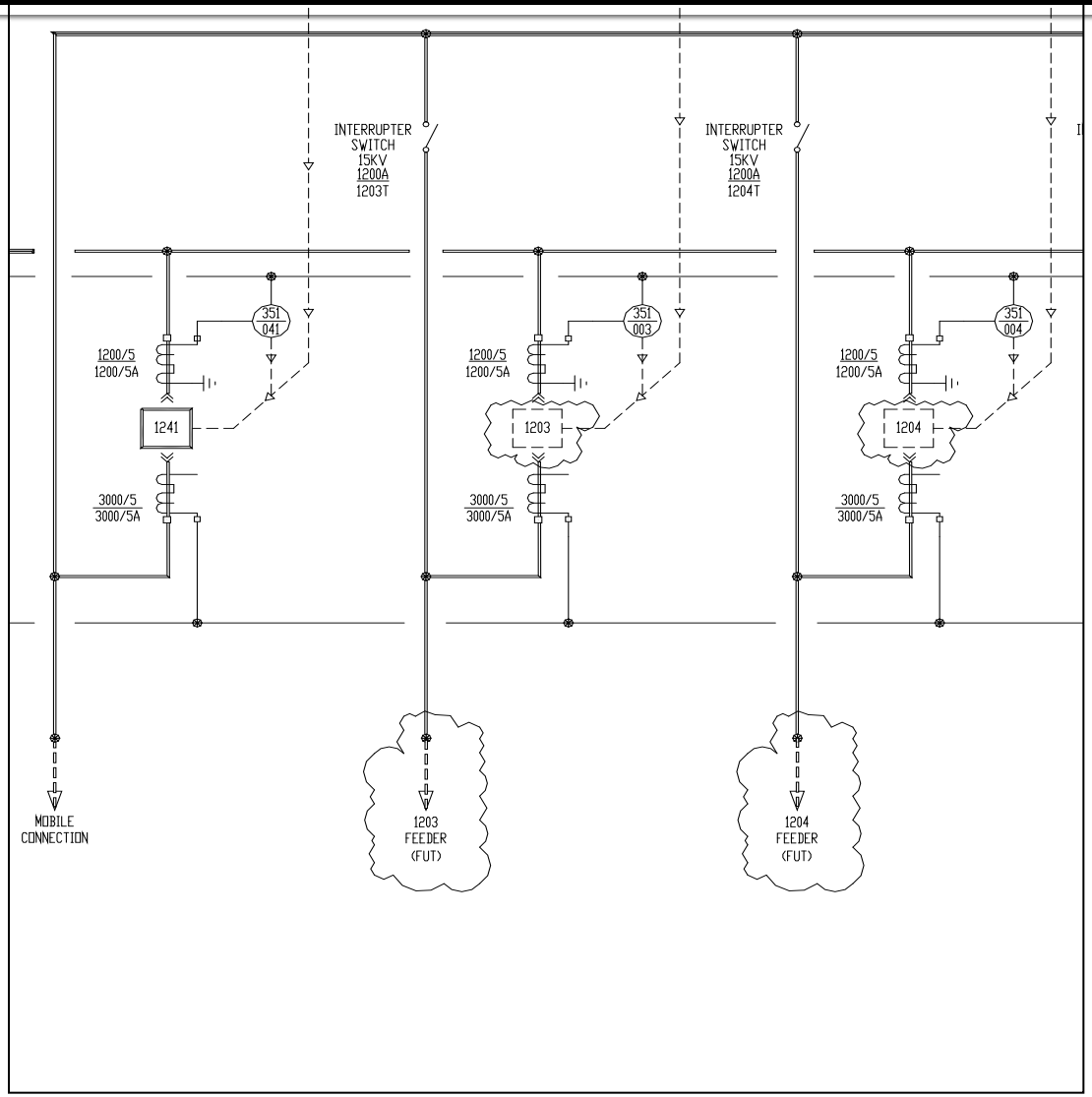
Cable Shield Terminates Here

Proximity Tester Will Work Here

Relaying Improvements

Make the design so they shut it off

- Maintenance bus
- Main-tie-main



Relaying Solutions

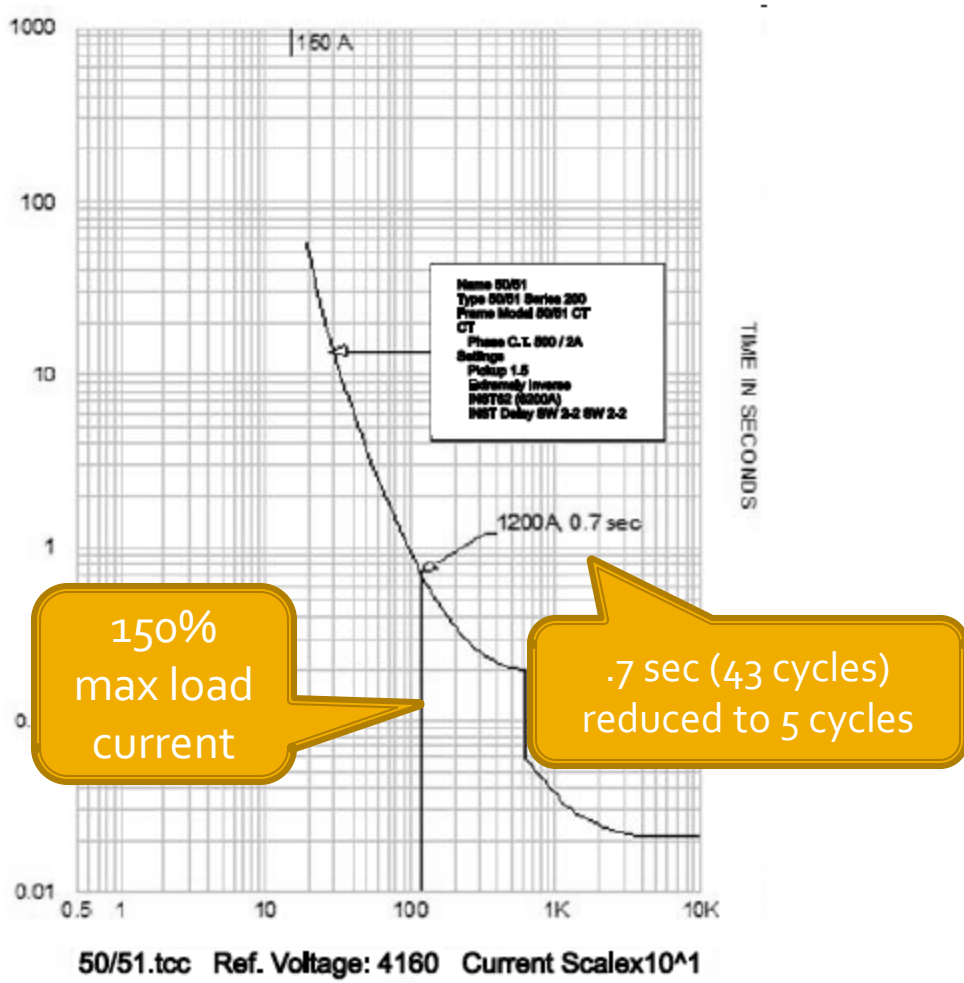
- Maintenance Switch enabled settings
- Instantaneous supervised by light, pressure, or sound
- Fast trip schemes using relays and communications
- Current Differentials
- Reduced time intervals of existing time overcurrent
- Breaker Failure

Maintenance Switch

Advantage	Disadvantage	Cost
Fast response 1.5 cycles plus breaker clearing	Selectivity compromised •Process hazard •Nuisance trip for auto start	43 switch Replacement relay Anuciator window 5k$
Use existing main and feeder overcurrents normally	Change must be made to operating procedure	
	Limited use on process system	

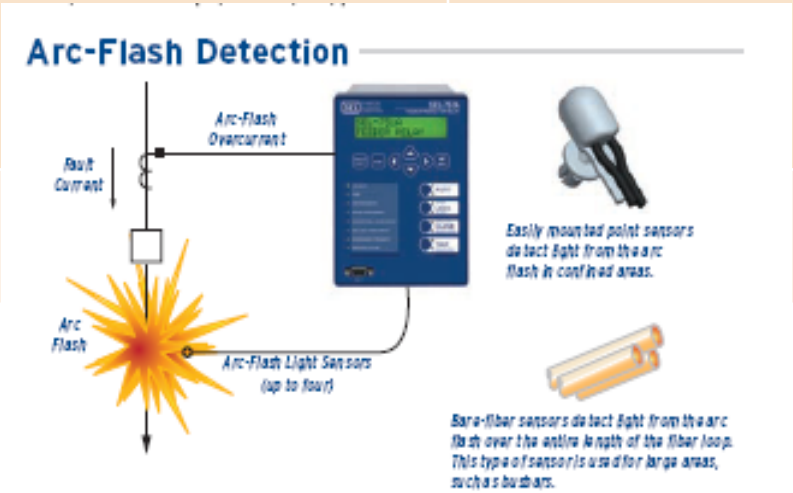
Maintenance Switch

- Risk of large motor auto start
- May put process operators in greater hazard
- What at risk procedures are you protecting for?



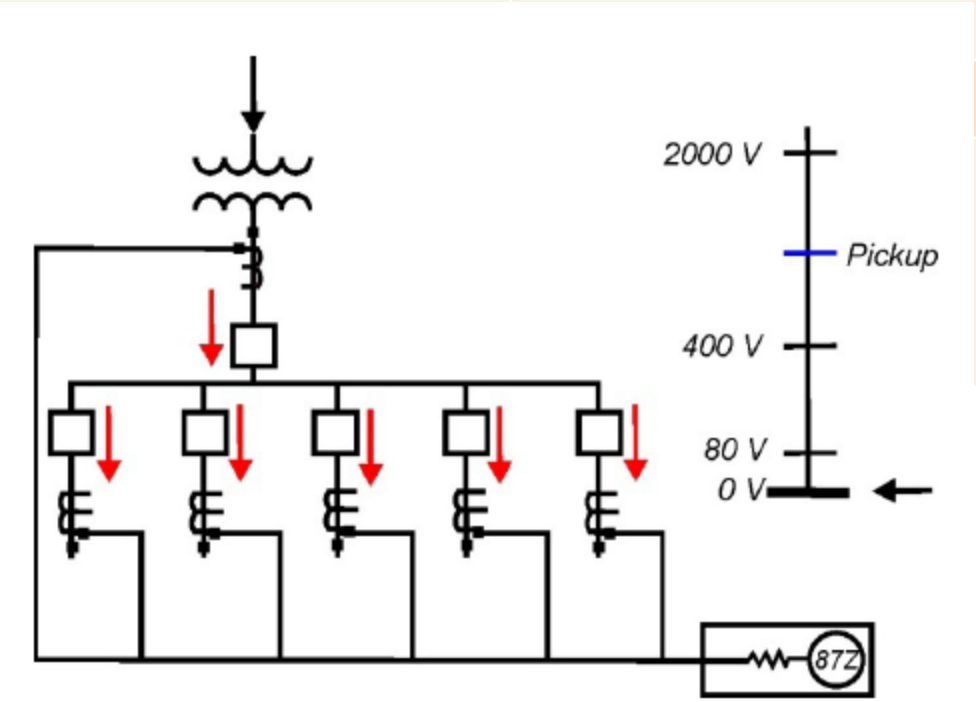
Light detection supervised instantaneous current

Advantages	Disadvantages	Costs
Fast response - .5 cycles plus clearing time	Fiber installation requires downtime	•Replacement relay with light detection •Install fiber •8k$ per feeder
Remains in service continuously, no decision about risk	May trip on LV Breaker and MV air breaker starter or fuse interruption	
Can protect xfmr secondary and cable compartment		
Cheaper to retrofit than bus diffs		



High Impedence Bus Differential

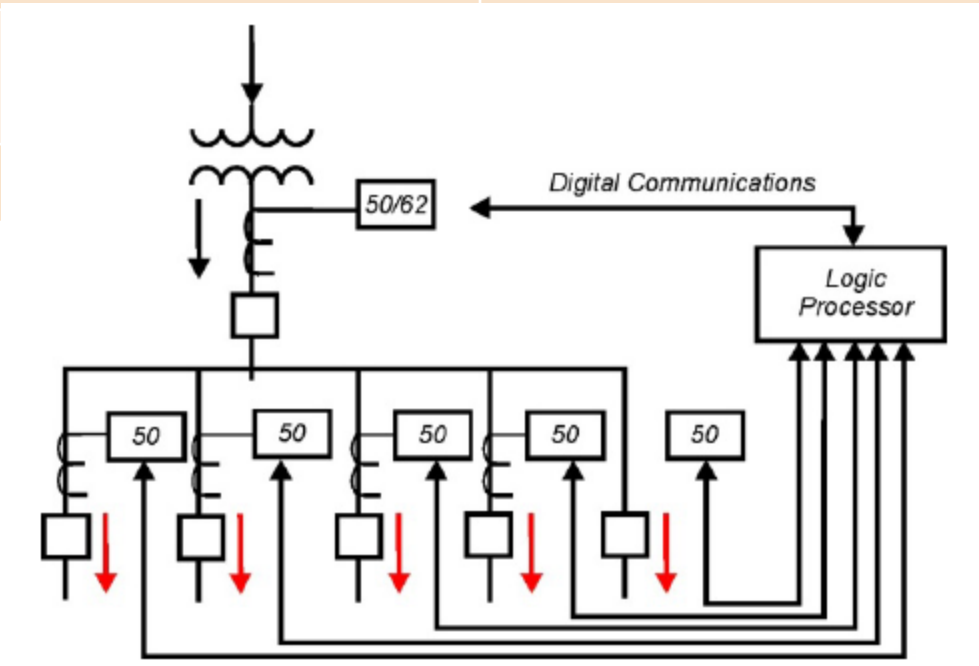
Advantages	Disadvantages	cost
Fast less than 2 cycles	High cost	Function of number of breakers bus 10K$
Very secure	Not fast enough to protect against pressure blast	
Calibrated to fault level		
Can be set for Ground fault on resistance grounded system depending on station service		



Arc Fault on Xfmr 480V secondary

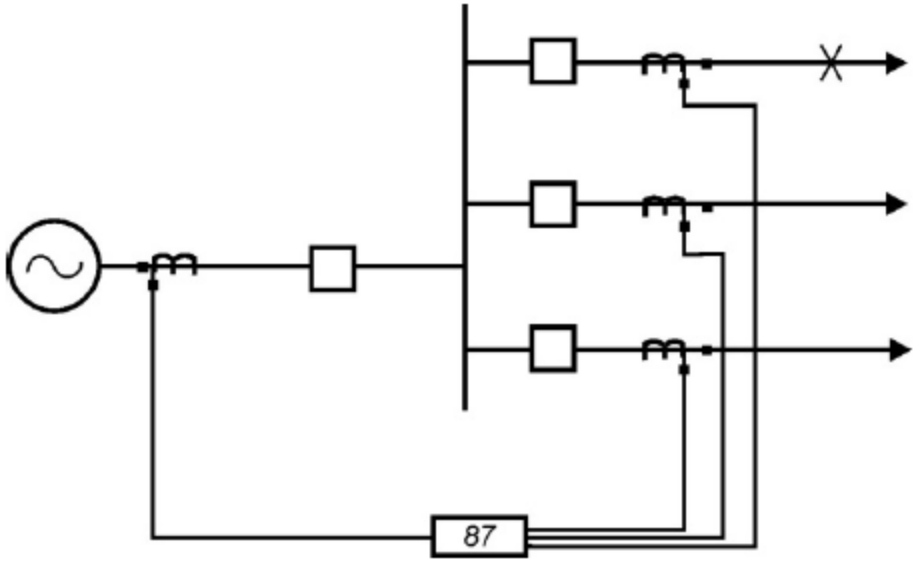
Zone Interlocking

Advantages	Disadvantages	Cost
Fast response – 5 cycle	No way to test functionality to final element	•Control wiring •Protection logic •Depends on # relay in service 9k$
Use of existing relay in many cases		
Wider reach		



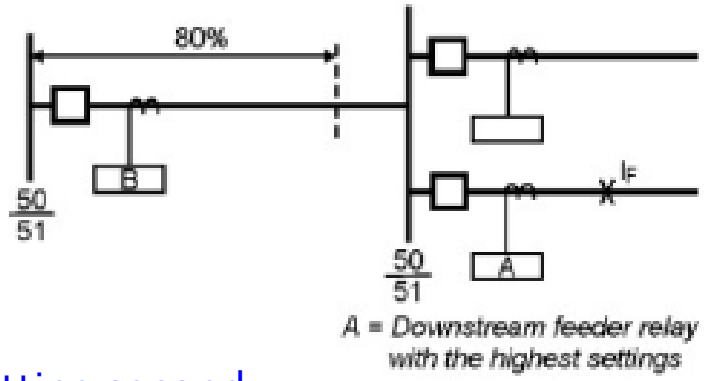
Low impedence bus differential

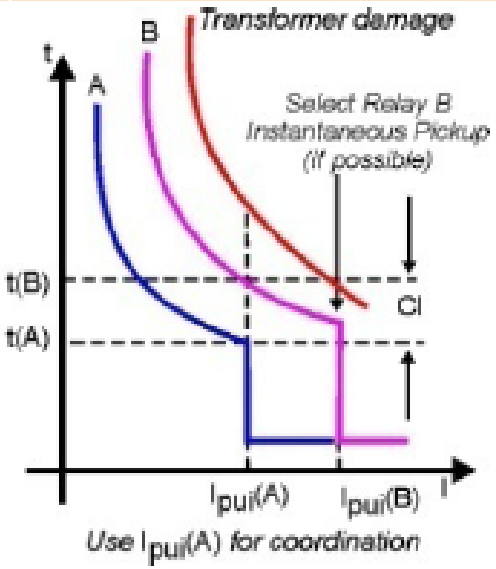
Advantages	Disadvantages	Costs
Fast	Can be a problem with saturation of ct if not ratio properly	Similar to bus diffs except add field cable cost
Can be set for ground faults		



Reduce coordination Time Interval

Advantages	Disadvantages	Cost
No Capital cost	Incident energy still relativley high	Coordination study
Can be applied using existing hardware	Compromises the .3 second time interval	
Setting second instantaneous at 125% A		

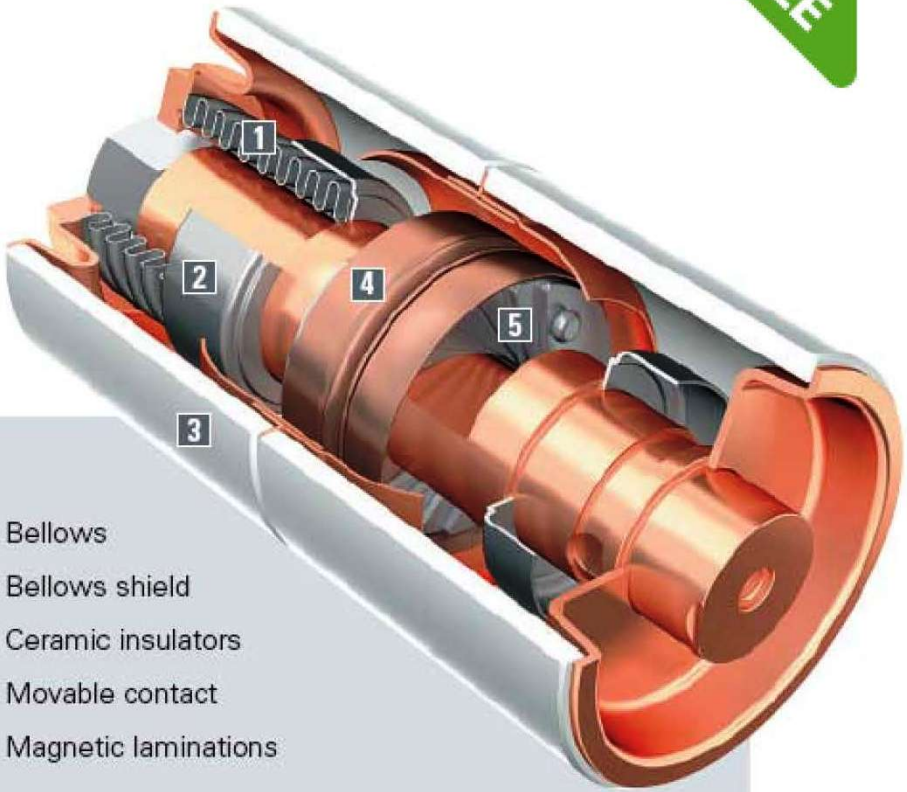




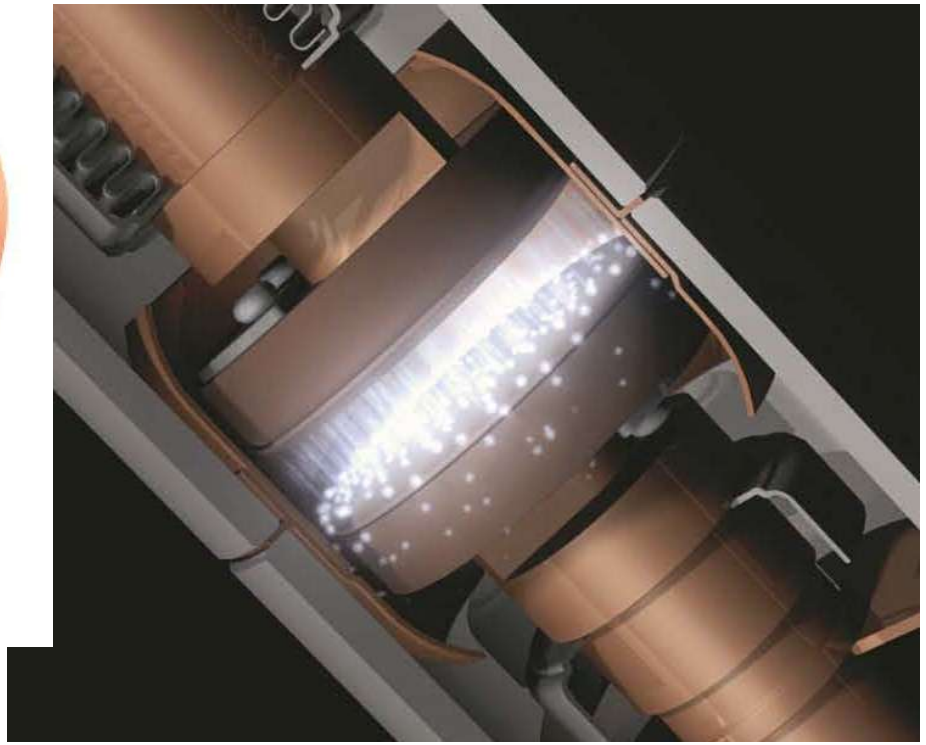
In LV systems setting second instantaneous at 125% of A

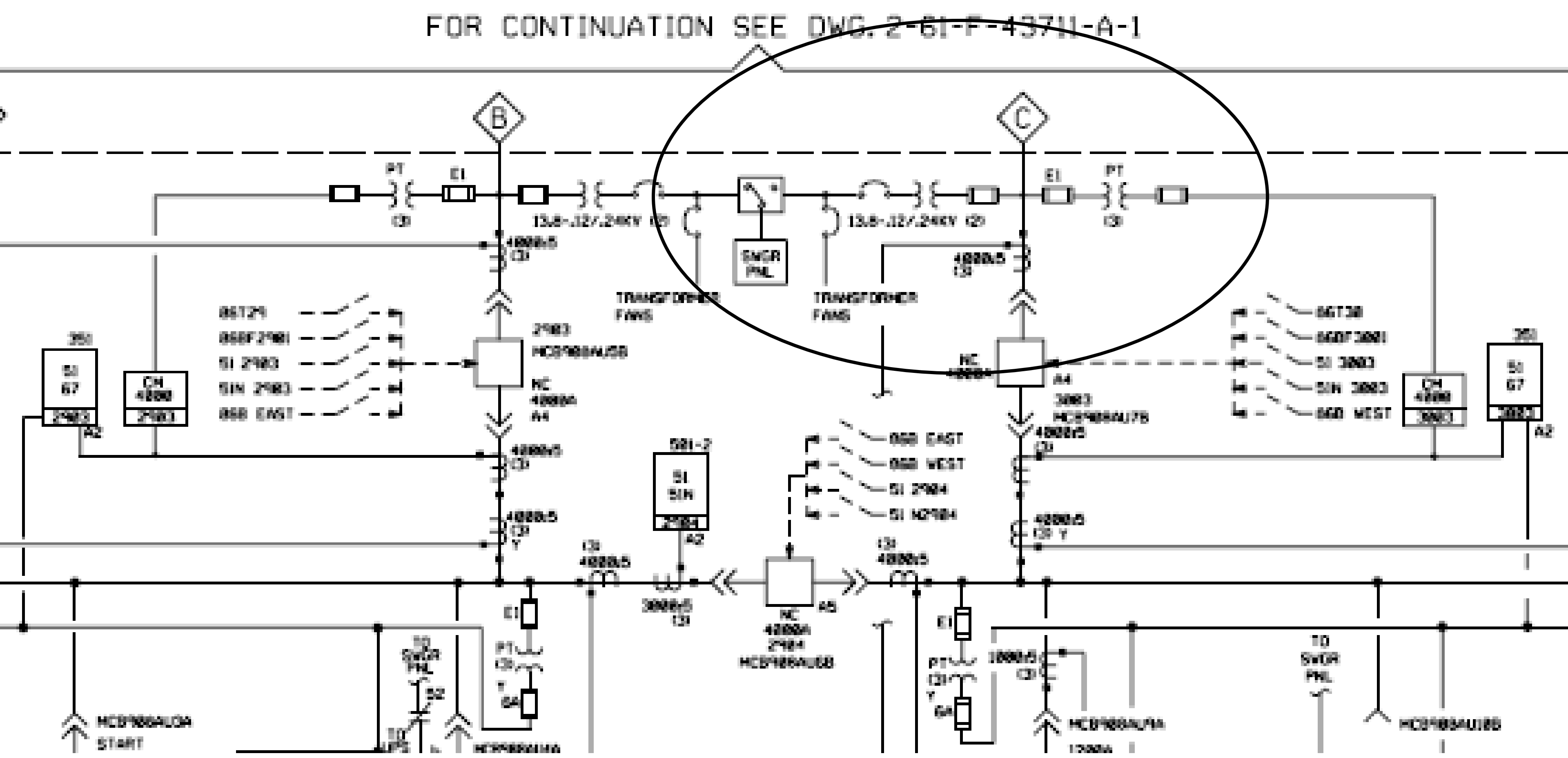
CPT's Installed in Switchgear

Modern Vacuum Bottles



1. Bellows
2. Bellows shield
3. Ceramic insulators
4. Movable contact
5. Magnetic laminations




FOR CONTINUATION SEE DWG. 2-61-F-43711-A-1
B
C
PT
E1
13.8-.12/.24KV (2)
SWGR PNL
TRANSFORMER FANS
TRANSFORMER FANS
4000/5 (3)
86T29
86BF2903
51 2903
51N 2903
86B EAST
2903
NC
4000A
A4
51 67
CM 4000
86T30
51 3003
51N 3003
86B WEST
3003
86B EAST
86B WEST
51 2904
51 N2904
51 51N
2904
NC
4000A
2904
A5
3000/5 (3)
TO SWGR PNL
52
TO UPS
START
1200A

Garyville installation

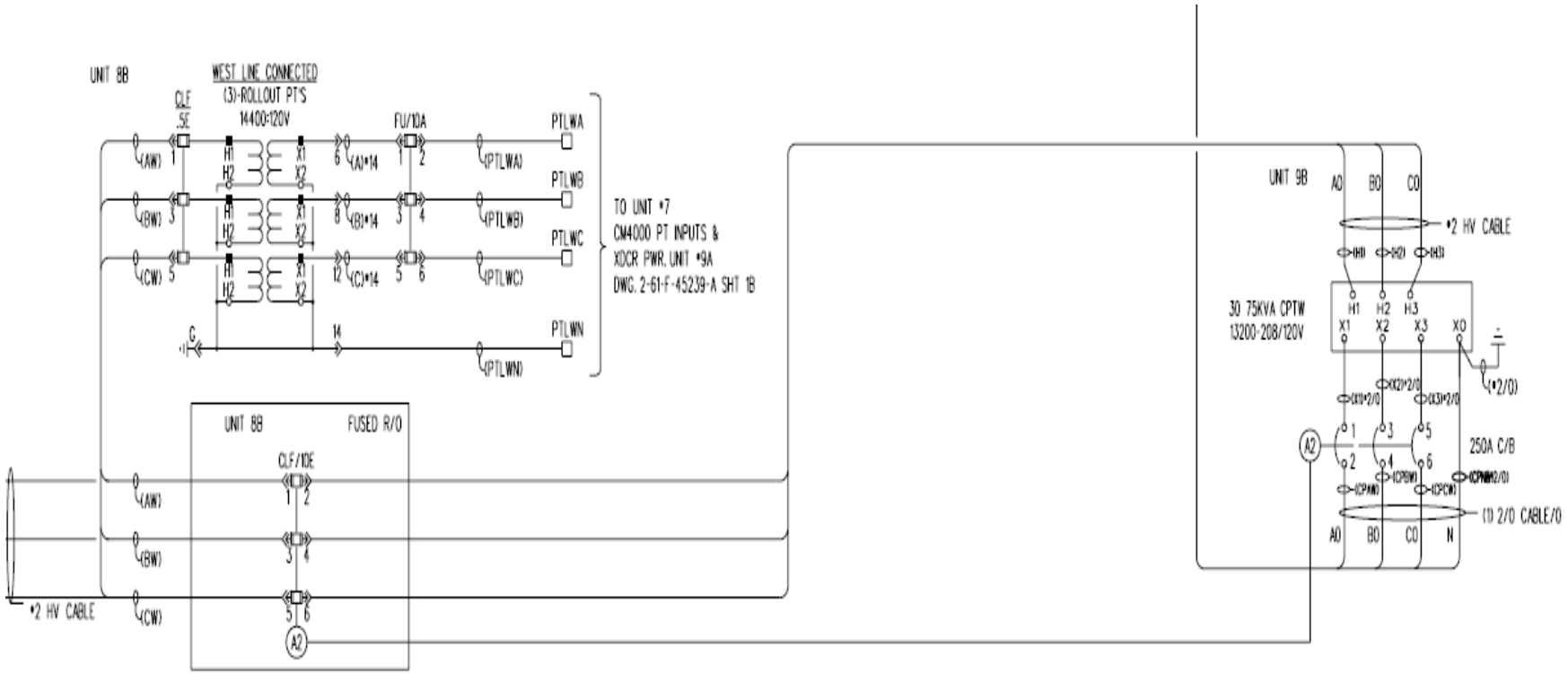
- 75kVA CPT
- Front accessed
- Less chance for smoke egress into other energized cubicles

CPT's in switchgear

Magnet wire underneath fault location

- Fault did not burn into the lower layers
- Fault set fire to epoxy on surface

For future installations
Consider Remote the CPT



Coordination issues

- Fuse should clear for cpt faults
  - Often time the fault is burried in the winding resulting in very long clearing time and open flames
- Too large a fuse size can not coordinate with high impedence diffs.
- Minimum diff setting on 200V with 3000/5 and 15 breakers results in a pickup of xxx amps

Coordination issue continued

- Desirable for diffs to be sensitive to switchgear groundfaults
- With 600A grounding resister small window of oportunitiy for coordination

Low Voltage

LV Switchgear

- High Resistant Grounding
- Max Transformer Sizing at 1500KVA
  - Best cost realization
    - Closer to load
    - Cable and tray cost vs. installation cost
    - Reduced fault current
    - Replacement strategy
- Use power breaker to feed big loads instead of mccb

LV MCC

- Separate turnaround power centers for aux load
- Size 5 starters Air Contactor / Vacuum Contactors/ Soft start
- Soft start vs. Auto Transformer reduced voltage start
- Reacceleration for transfer and voltage dips

LOW VOLTAGE SWITCHGEAR

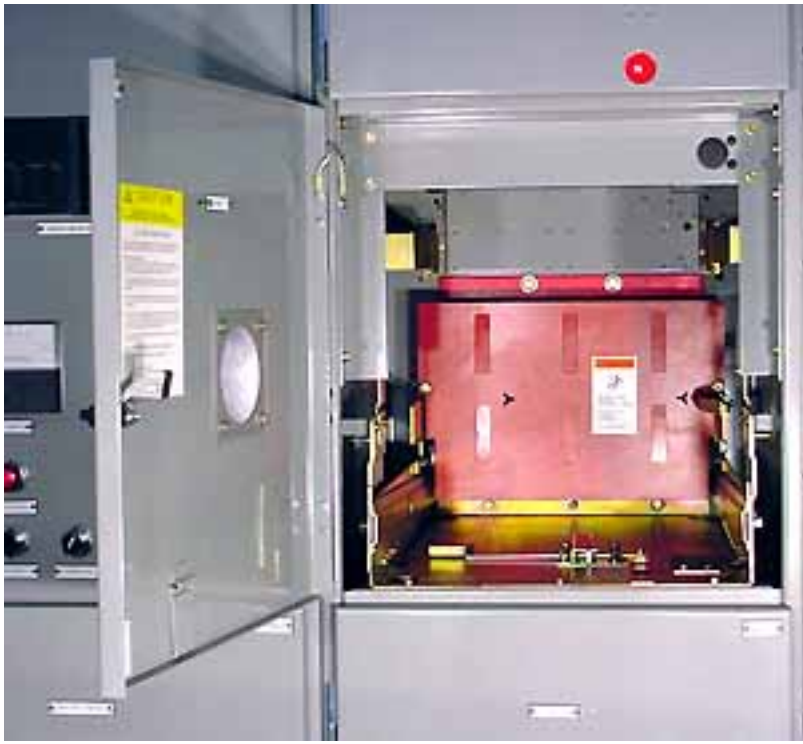
- **Current limiting fuses**
- **Operate away from arc flash hazard distances**
  - Extended racking handle
  - Close door racking

Relation between LV Bolted and Arcing Fault Current

Bolted Fault Current	Arc Fault Current
@ 480 V	
10 kA	= 6.56 kA
20 kA	= 11.85 kA
30 kA	= 16.76 kA
40 kA	= 21.43 kA

LOW VOLTAGE SWITCHGEAR

- Electrically operate breakers only
- Insulated buses to minimize phase to phase fault potential and touch potential.
- Shutters
- Boots or mastic tape
- Two (2) Breaker indicating lights
  - Red for closed breaker
  - Green for breaker open

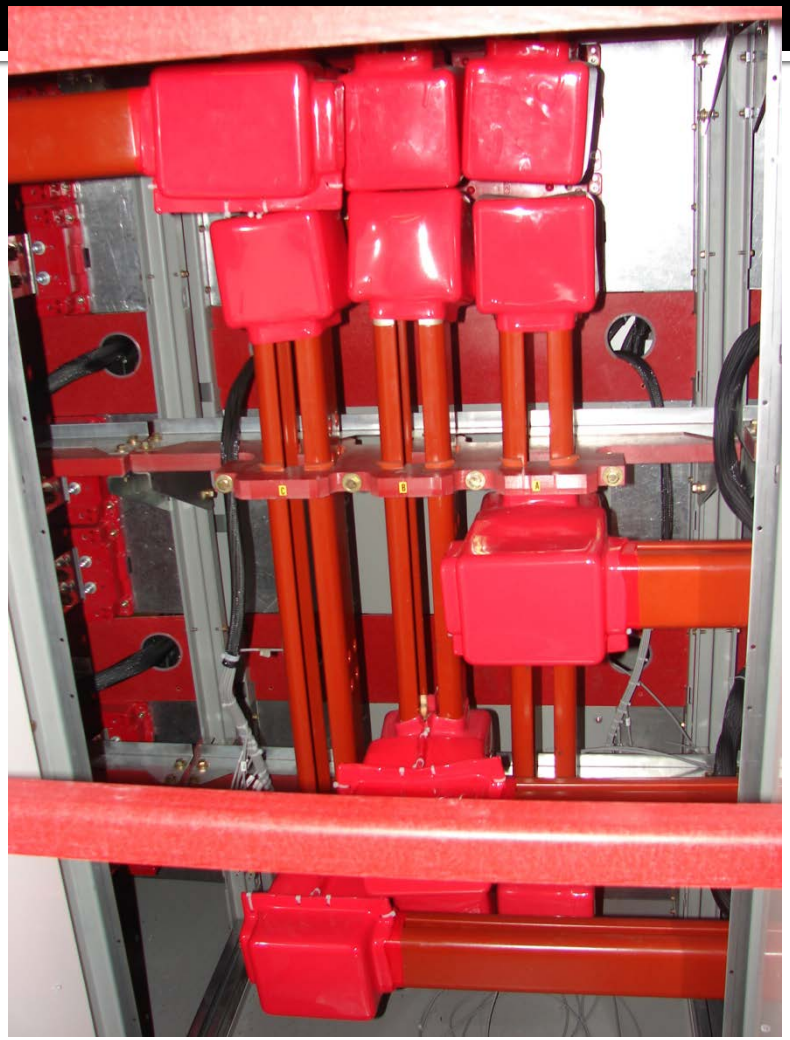


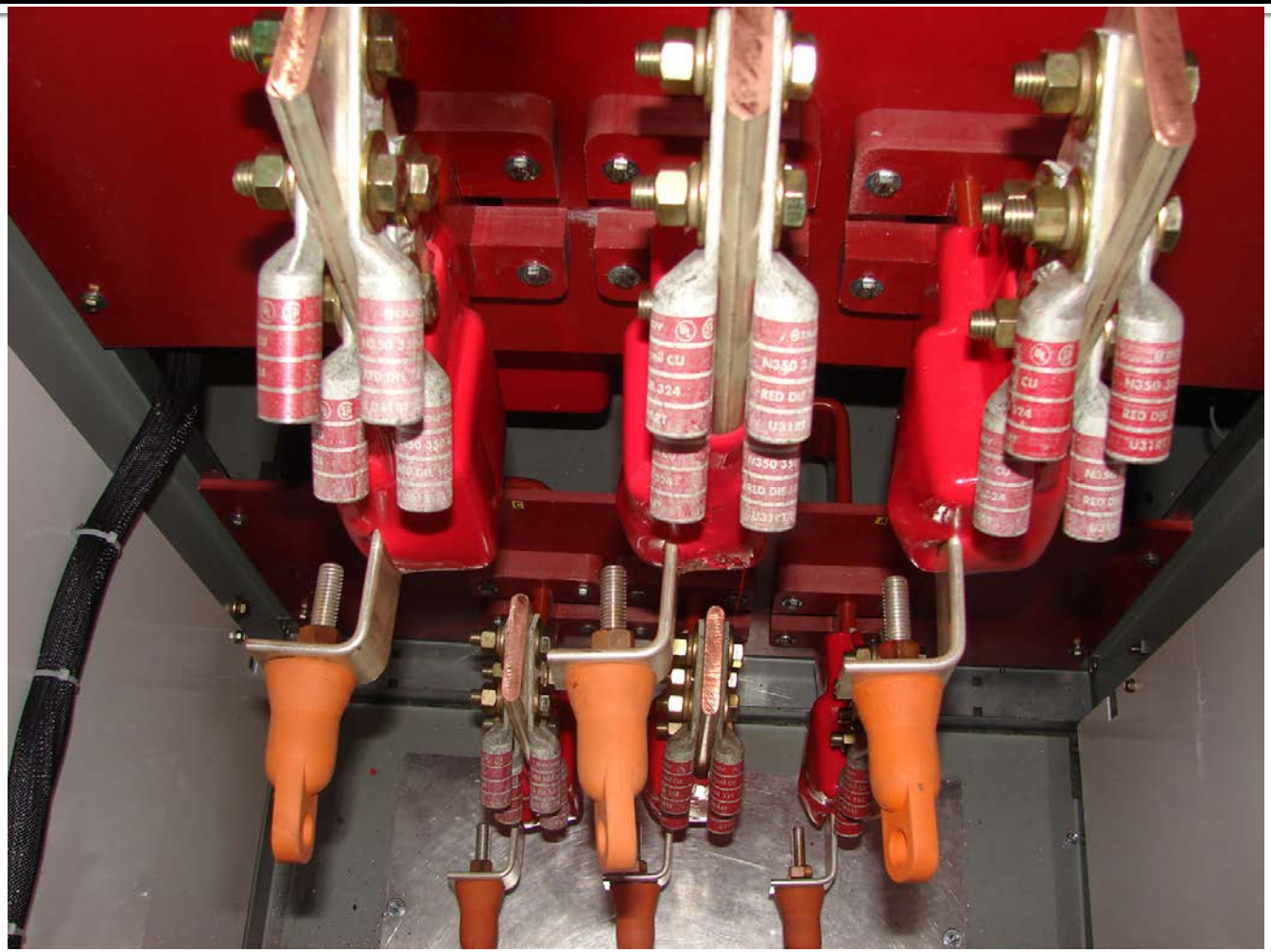
LOW VOLTAGE SWITCHGEAR

- Barriers between cubicles
- Barriers between main bus & cable compartments.
- Stagger bus on feeder runbacks for cable connections
- Extra depth cable compartment

Shaped Copper

- Less Layer bolted together
- Stronger short circuit shapes





Cable Spacing

- The requirements in the standard can allow you to design more cable than you can install.

Low voltage faults on high side

- Bare lugs
- Mechanical lugs
- Upstream clearing time given cable impedance
- Maint switch

80kA for .4 sec at 508VAC

Solid ground vs. high resistance ground 85kA .5sec at 508volts

Solid Ground

HRG

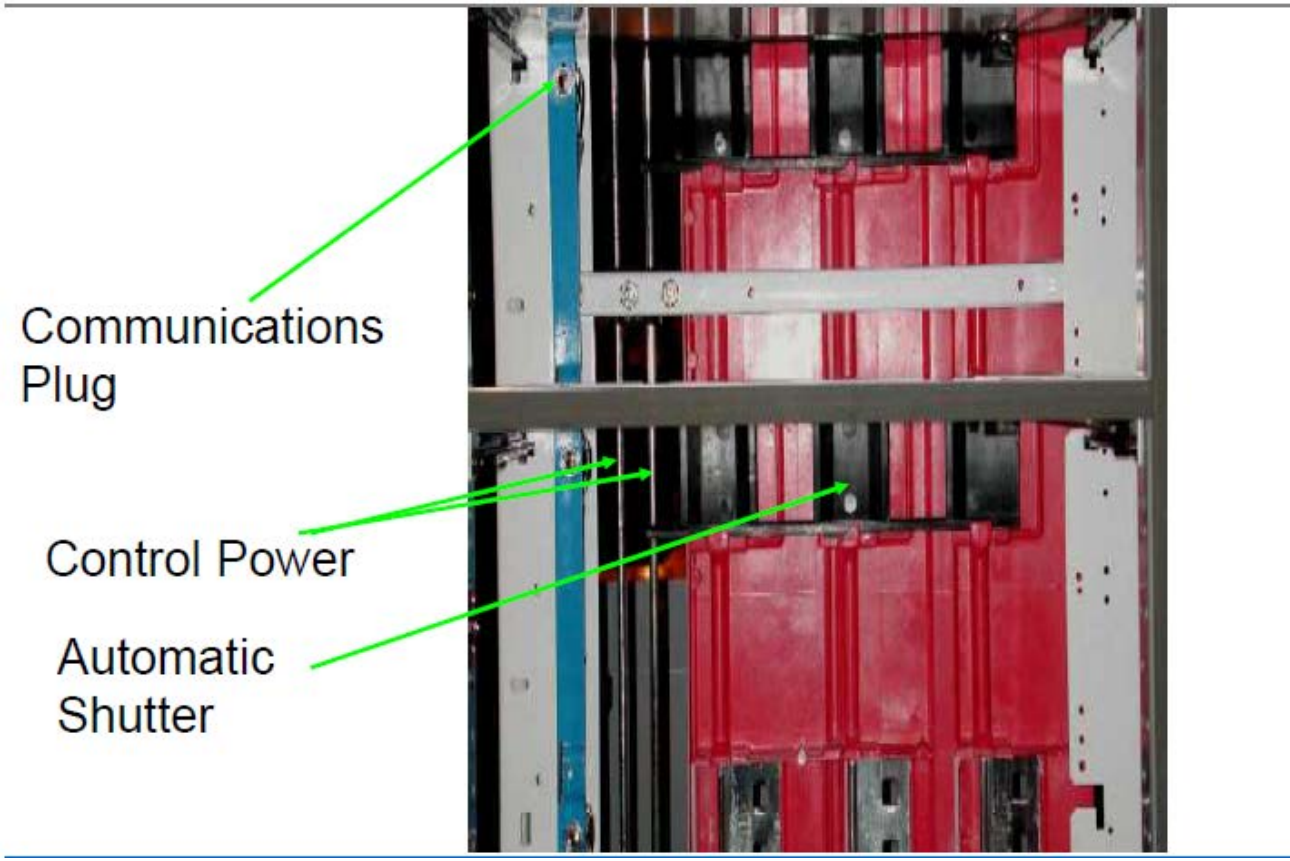
UnInsulated vs. Insulated Bus

Uninsulated Main Bus
85kA 635V
530msec 63psi
1.5 to 3 cal/cm2

Insulated Main Bus
85kA 635V
13.7msec 13.2psi

- Fully shuttered
- Stabs encapsulated prior to engagement

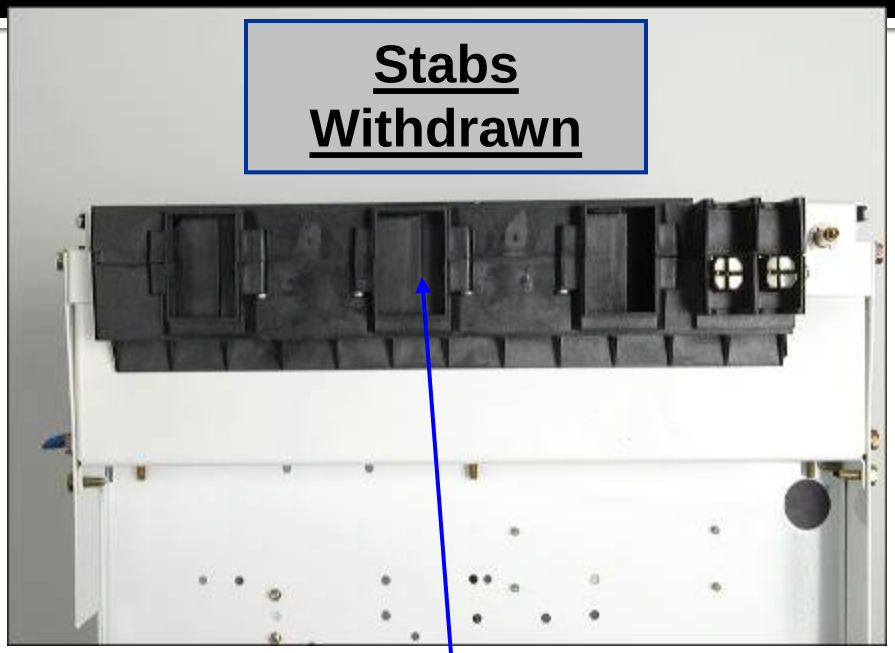
480 Volt Isolation

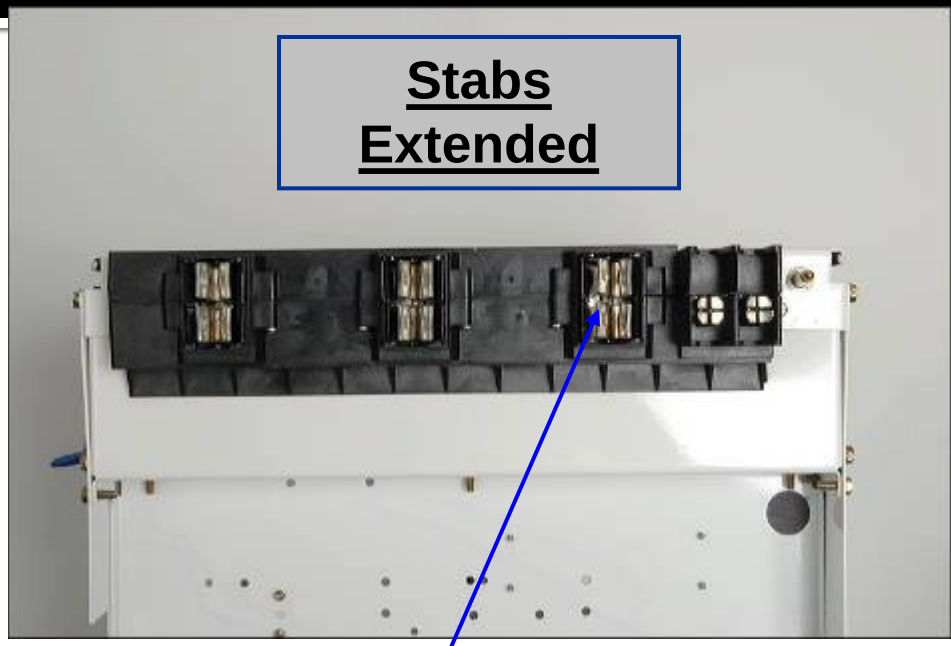


LV MCC

- Handle extension for operating disconnect
- Smarts for first tier testing
- Remote low energy source for troubleshooting

What is our solution?





- **480 Volt Isolation via stab shutter**

- **Extendable and Retractable power stabs – up to 400 Amp Stab**
  Allows you to engage or disengage the stab with the vertical bus while the door is closed keeping you at a safe distance while performing this operation

38kV 40kA 55000 lbs of thrust notice the front corner of the gear

The End

Next Generation Arc Resistant

Case Study

Major Arc Flash + Good Practices = No Injuries Case Study

Joe Rachford
Gallatin Steel
Joe.Rachford@Gallatinsteel.com

Major Arc Flash Fault + Good Practices = No Injuries

Major Arc Flash Details:

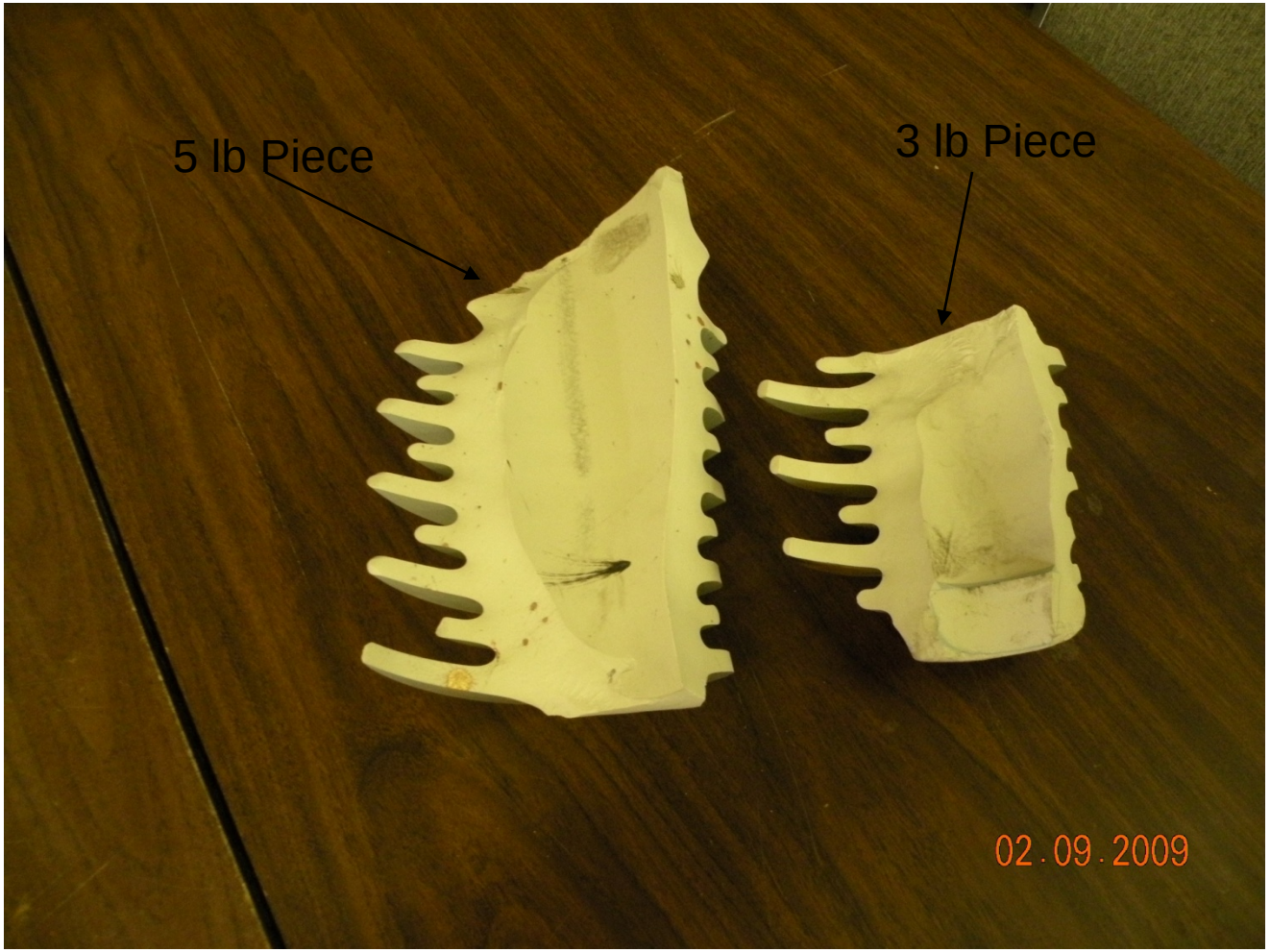
- Arc Flash Incident Energy = 43 cal/cm2
- Arc Flash Boundary Zone = 48 foot
- Power Fed From Two Parallel 129 MVA Transformers for Arc Furnace Operation
- Arc Fault Traveled 15 foot to Breaker
- Large White Flash and Loud Noise Observed During the Fault
- 5 lb Piece of Porcelain Landed 70 foot Away

Substation Layout

Arc Flash Starting Point

Arc Flash Traveled to Breaker

Porcelain Found 70 foot Away



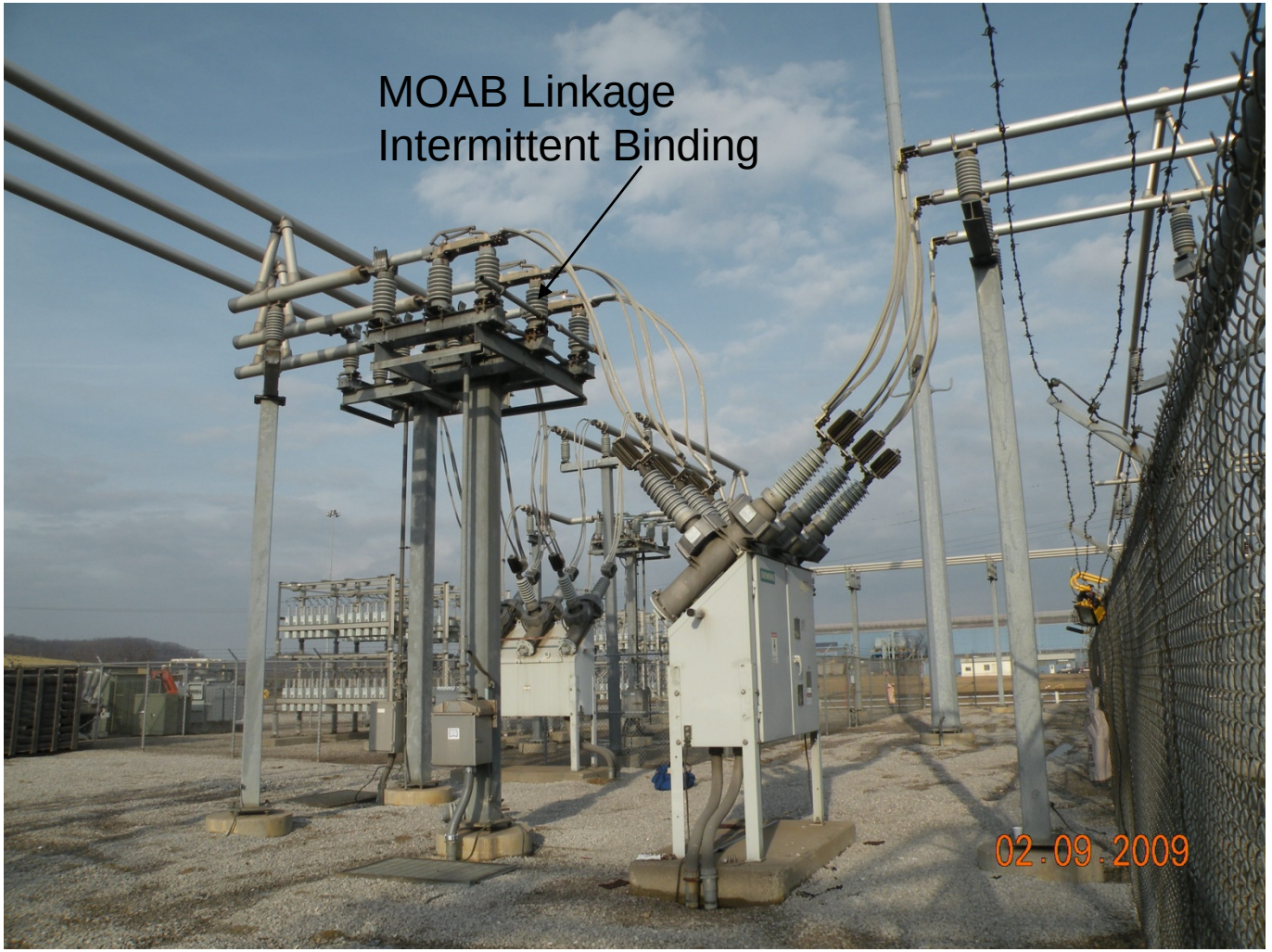
Secondary Damage

Close Up Secondary Damage

Root Cause 1


MOAB Control Box Changed
That Day Due to Motor Failure
The Previous Week
02.09.2009

Root Cause 2



Summary

- Arc Flash Initiated by Misalignment of MOAB Arms Due to Adjustment of Control Box and Linkage Problems
- Arc Flash Traveled 15 foot Down the Bus to the Breaker Bushings
- Mechanical Parts Found 70 foot Away and Truck Panel Had Hole Punched in Door

MV MCC Case study

Here to share a good news story!

- THE JOB: Change the rotation on a 1000 Hp 2300 V motor
- UNEXPECTED: Motor controller did not fit the procedure
- POOR DECISION: Improper grounds, improperly placed, no indication of grounds

What Happened?

- Motor leads were swapped at the contactor
- Several days passed
- ESWP released without removing grounds
- Returned to operations
- Operator closed no-load switch
- Switch flashed phase to phase to phase to ground

The Fault:

- 38 kA
- 210 mS
- Cleared by an upstream breaker
- Plant experienced an emergency outage
- Hot gasses pushed door open right were operator was standing

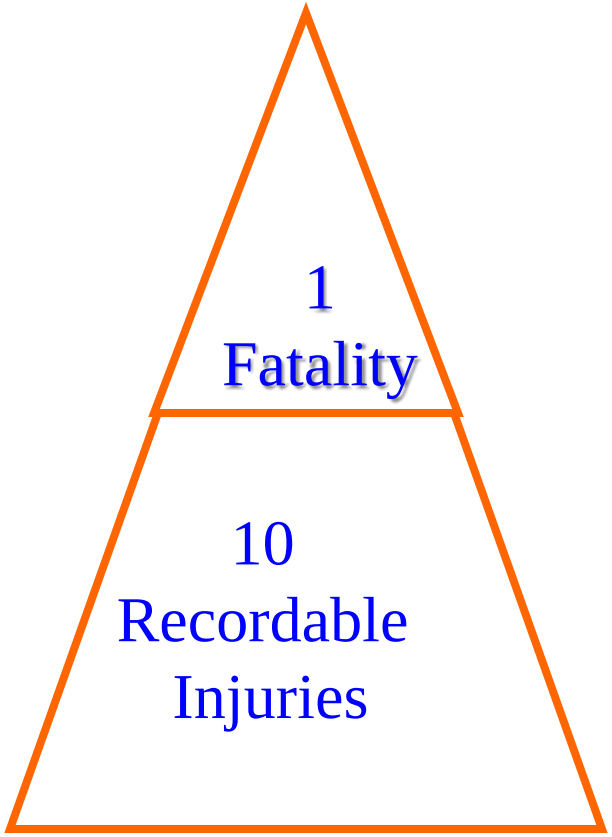

ATTENTION


DANGER
WARNING

NFPA 70 E 2011

Exxon Mobil - Columbia

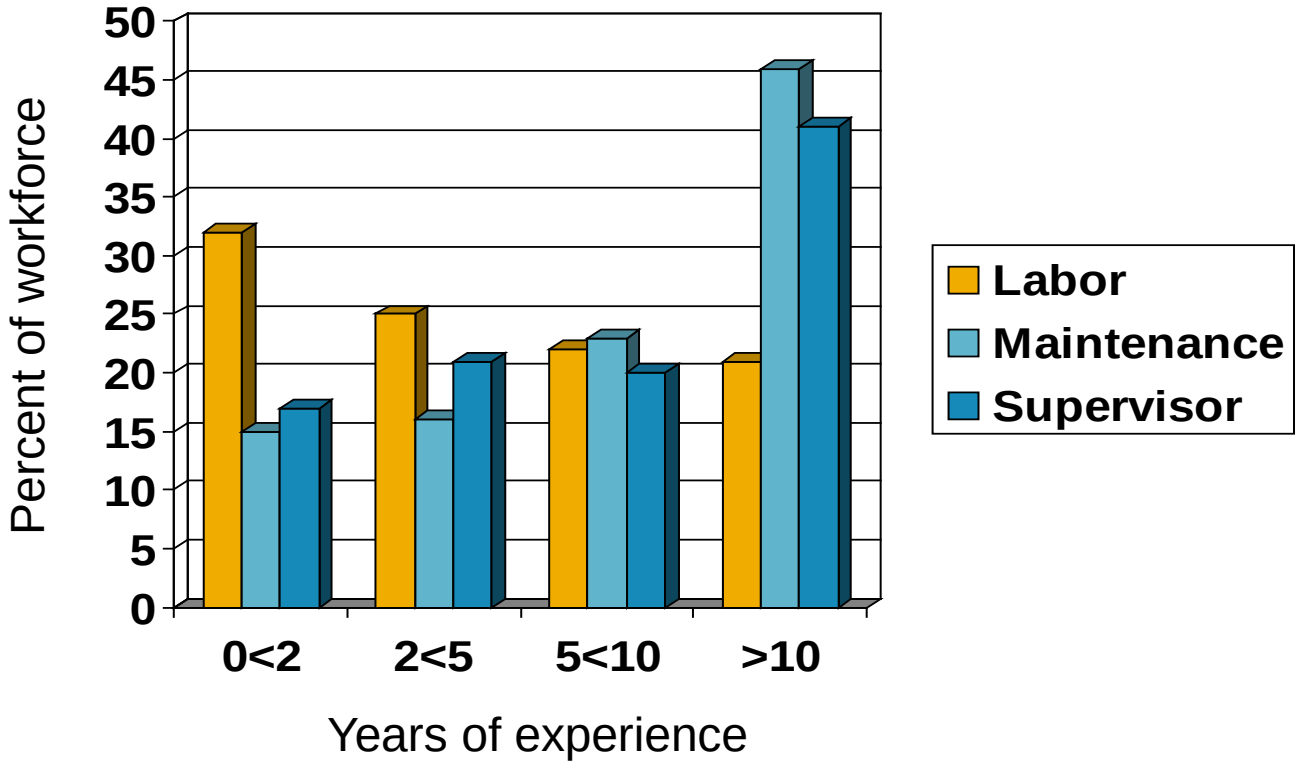
Safety Triangle



Preliminary findings

Organization of work issues

Experienced maintenance personnel and supervisors had a larger proportion of injuries; less experienced laborers also had more injuries



Indicator Burn Energy

- Indicators are pieces of 150g/m^2 black cotton cloth (cretonne)
- 1.2 cal/cm^2 and below will not ignite an indicator
- 1.5 to 2.0 cal/cm^2 will ignite an indicator

MV 36KA on Rear
15KV 0.5s 25kA Dual
Burner Indicator AT
Top Left of Door

Kema Powertest Powell Temperature Program
Data Summery

DAS Operator: Alex Jushcyshyn
Date: 2/14/2007
Time: 2:15pm

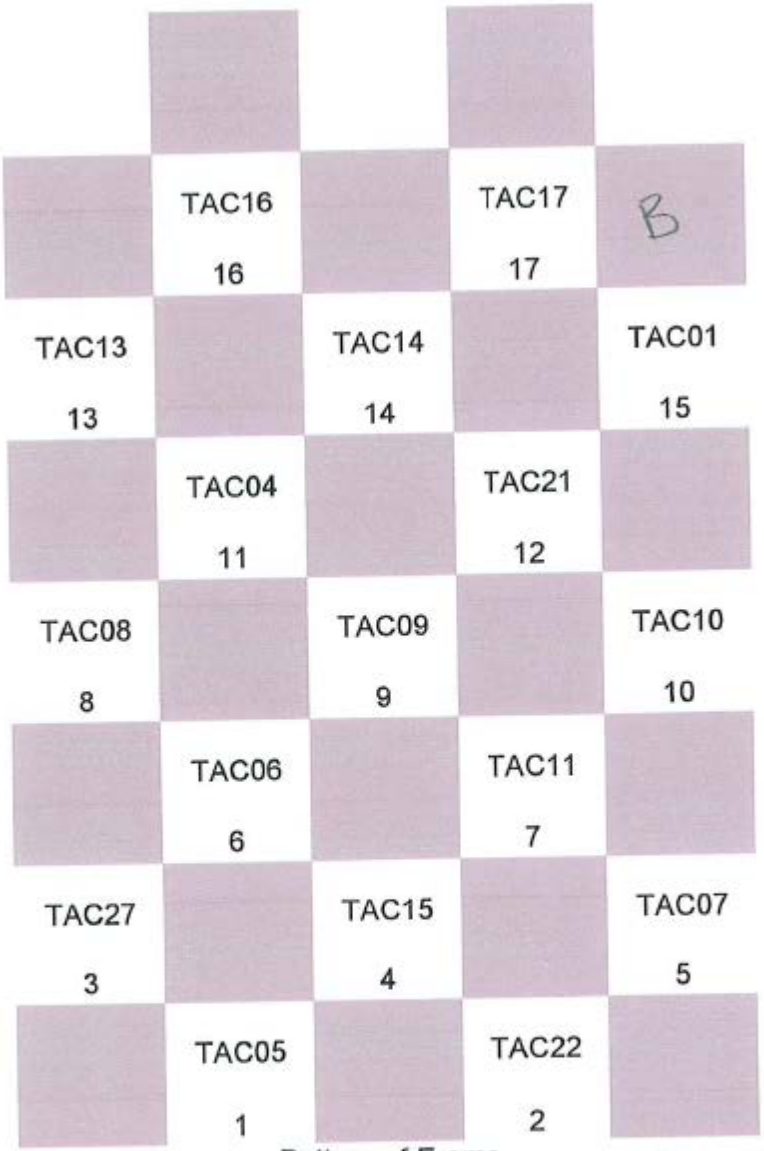
Test Number: 07025-b3
Trial Number: #2

KEMA

Data Channel	Avg Start Temp Deg C	Max Temp Deg C	Max Heat Energy cal/cm^2	Time to max heat sec
1	8.11	8.40	0.04	0.95
2	7.21	8.30	0.14	0.15
3	5.96	6.50	0.07	0.80
4	8.11	9.30	0.16	0.15
5	7.96	8.40	0.06	0.00
6	7.60	8.20	0.08	0.85
7	8.10	8.70	0.08	0.25
8	6.90	8.20	0.17	0.25
9	8.34	9.40	0.14	0.00
10	7.28	9.80	0.33	0.85
11	8.68	9.90	0.16	0.85
12	8.44	10.20	0.23	0.85
13	6.93	9.40	0.32	0.45
14	8.63	11.60	0.39	0.45
15	9.50	13.30	0.50	0.55
16	9.47	16.50	0.92	0.85
17	10.02	19.60	1.26	0.50

Max Temp, Max Heat, and time to max is based on data from 1 sec after test event.

Indicator and calorimeter location



Bottom of Frame

Effects of an Internal Arc Fault

- Mechanical stress from pressure increase
- Thermal stress from the radiated heat
- Release of toxic gases
- Direct injury from:
  - The pressure wave
  - Contact with energized parts
  - Radiation from intense light
- Indirect injury from airborne debris

What is Incident Energy?

- Energy (heat) per unit area received on a surface located a working distance away from the flash location

- Working distance is between worker's torso & arc-flash location

What is Incident Energy?

- Unit of measure is cal/cm^2
- One cal/cm^2 is equivalent to the amount of energy produced by a cigarette lighter in one second

Incident Energy (cal/cm^2)	Degree Burn
1.2	2nd degree burn to skin
4	Ignite a cotton shirt
8	3rd degree burn to bare skin

What is Incident Energy?

- Inversely proportional to the working distance squared *(Double the distance = ¼ the incident energy)*
- Directly proportional to the time duration of the arc and to the available bolted fault current *(Double the arc duration or fault current = double the incident energy)*

Direct Exposure to the Arc

An arc emits a strong radiation, mostly UV light.

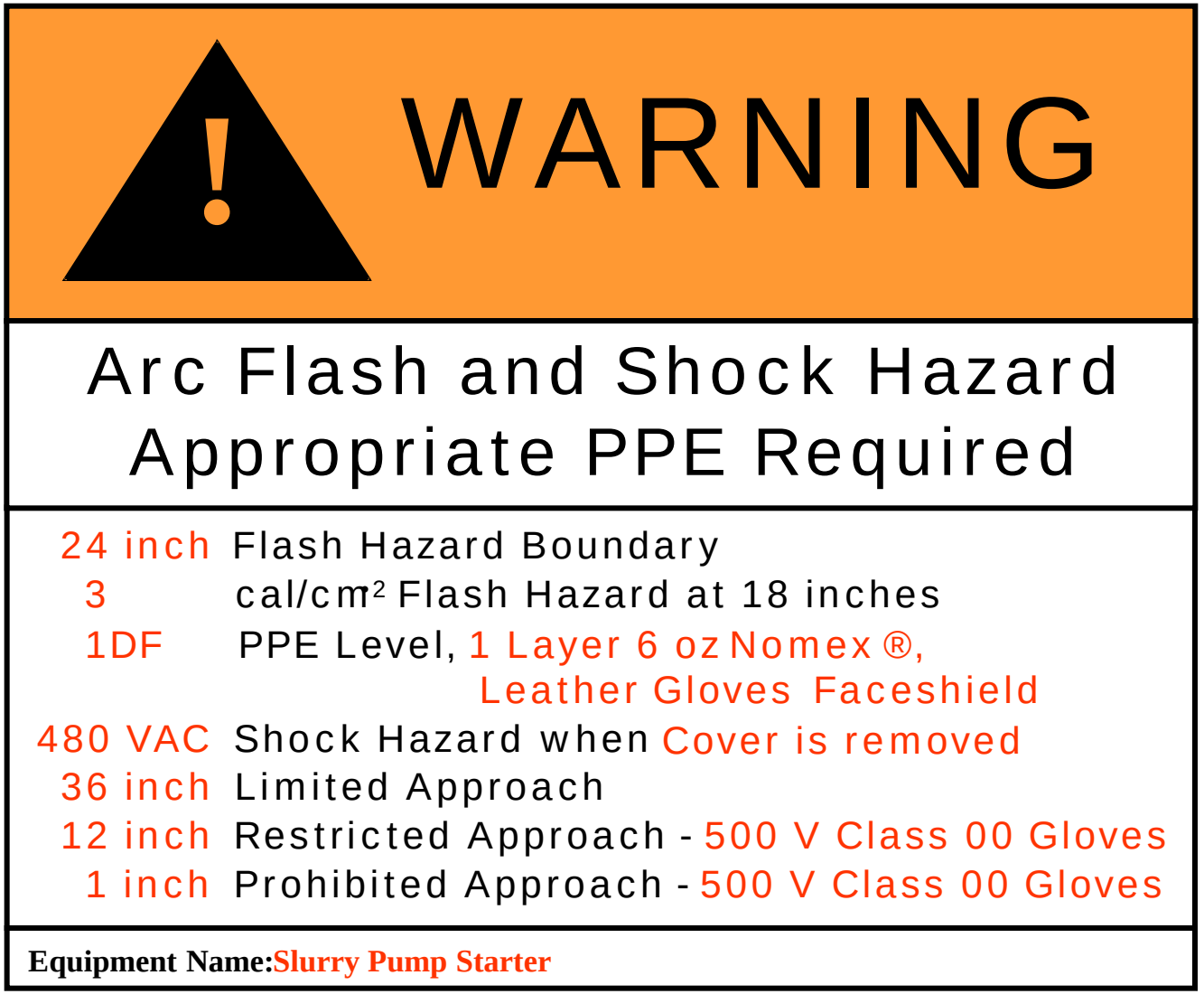
System voltage, phase spacing, fault current, fault duration and the distance from the arc all contribute to the effect.

Skin Temperature

Volts	Fault Current	Duration	Distance	Temp rise
480	40kA	0.1 sec	24 in	310C
13.8kV	40kA	0.1 sec	24 in	8000C
13.8kV	40kA	0.1 sec	120 in	200C

Look-up Table Example Cal/cm² 480 & 600 V Switchgear

Short Circuit Current (kA)	Fault clearing time		
	0.5 s	0.33 s	0.1 s
65 kA	74 cal/cm²	49 cal/cm²	15 cal/cm²
55 kA	63 cal/cm²	42 cal/cm²	13 cal/cm²
45 kA	52 cal/cm²	34 cal/cm²	11 cal/cm²
35 kA	41 cal/cm²	27 cal/cm²	8.1 cal/cm²
25 kA	30 cal/cm²	20 cal/cm²	5.8 cal/cm²
15 kA	20 cal/cm²	12 cal/cm²	3.6 cal/cm²



Courtesy E.I. du Pont de Nemours & Co.

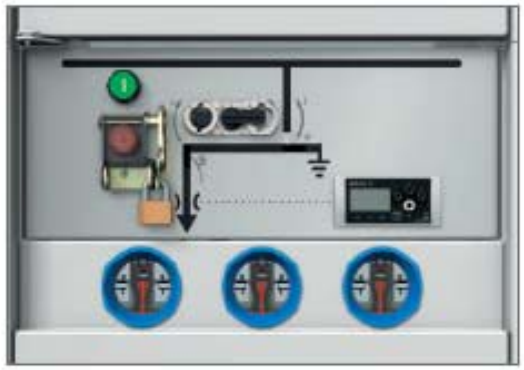
What is PPE?

- Personal Protective Equipment (PPE) is clothing, gloves, tools, face protection, and glasses designed to protect personnel from arc-flash hazards.

Category	Cal/cm^2	Clothing
0	1.2	Untreated Cotton
1	5	Flame retardant (FR) shirt and FR pants
2	8	Cotton underwear FR shirt and FR pants
3	25	Cotton underwear FR shirt, FR pants and FR coveralls
4	40	Cotton underwear FR shirt, FR pants and double layer switching coat and pants

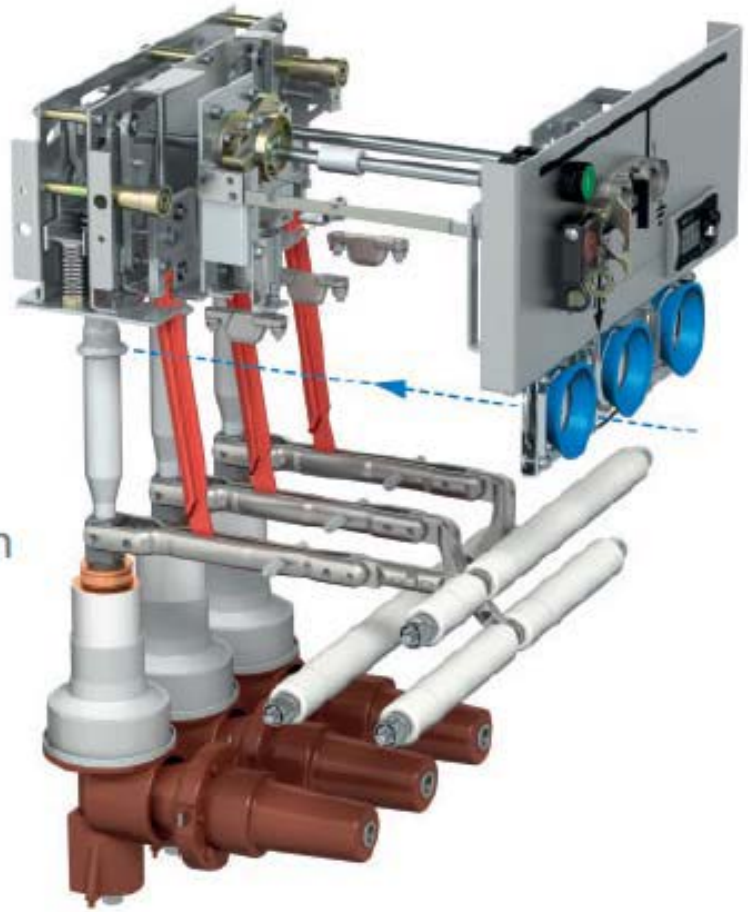
NFPA 70E PPE Categories

Insulation clad switchgear



Earth position

Operating position



Remote racking LV MCC

- **Features**
  - **Status Indication**
    - Stab position indication
    - Stab shutter position indication

The Freedom FlashGard™ Bucket

Racking Tool Receiver

Unit Latch

Power Stab Position
- Connected
- Disconnected

Internal Shutter Position
- Open
- Closed

Handle Mechanism

Pilot Device Island
- Start, Stop, Auto/Man

Breaker

Starter

Medium Voltage Motor Control

- 2 high construction
  - Separate raceway for top and bottom cable
- Locate 2 high spares to minimize exposure
  - Top entry installation

    = top spares
  - Bottom entry installation

    = bottom entry spares