Innovative Techniques for Mitigating Arc Flash Exposure

Presented at
MEMSA 2009 Annual Meeting & Technical Symposium
As more and more industries address arc flash electrical safety concerns, they are discovering a high risk associated with what used to be normal maintenance tasks. In many cases, the excessively high arc flash incident energies make it so all maintenance must be done with equipment de-energized -- not always acceptable to the process industries. This paper will address the multiple ways to significantly lower arc flash incident energy exposure by new system design and products, retrofits, retro-fills, equipment modifications, alternate protection settings, etc. In most cases, NFPA 70E Hazard Risk Category 2 or lower can be obtained. Examples will be discussed.
INTRODUCTION

What is Arc Flash?

NFPA 70E defines flash hazard as “a dangerous condition associated with the release of energy caused by an electric arc.”
Failed 50kA 5kV available fault current 0.5sec
INTRODUCTION

Failed 50kA 5kV available fault current 0.5sec
INTRODUCTION

• Large Hydro in Pacific NW
• 6.9kV Swgr
• Racking in Breaker
• AF occurred
• One worker injured
• 4+ years, $10+ million
<table>
<thead>
<tr>
<th>Hazard Risk Category</th>
<th>Clothing Description (Typical number of clothing layers is given in parenthesis)</th>
<th>Required Minimum Arc Rating of PPE [J/cm²(cal/cm²)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Non-melting, flammable materials (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight at least 4.5 oz/yd² (1)</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>FR shirt and FR pants or FR coverall (1)</td>
<td>16.74 (4)</td>
</tr>
<tr>
<td>2</td>
<td>Cotton underwear – conventional short sleeve and brief/shorts, plus FR shirt and FR pants (1 or 2)</td>
<td>33.47 (8)</td>
</tr>
<tr>
<td>3</td>
<td>Cotton underwear plus FR shirt and FR pants plus FR coverall, or cotton underwear plus two FR coveralls (2 or 3)</td>
<td>104.6 (25)</td>
</tr>
<tr>
<td>4</td>
<td>Cotton underwear plus FR shirt and FR pants plus multilayer flash suit (3 or more)</td>
<td>167.36 (40)</td>
</tr>
</tbody>
</table>

INTRODUCTION
INTRODUCTION

Too Much PPE is Just as Bad as Not Enough!
This is what we want
Reducing Arc Flash Hazards Requires a Total System Solution Approach
SOLUTIONS THAT REDUCE ARC FLASH INJURIES and DAMAGE

What determines arc flash energy?

- Available fault current
- Time required to clear the fault
- Distance from the arc
SOLUTIONS THAT REDUCE ARC FLASH INJURIES and DAMAGE

• Label Equipment & Train Personnel
• Minimize Risk with Good Safety Practices
• Reduce Available Fault Current
• Faster Clearing Time
• Move People Further Away
• Redirect Blast Energy
• Prevent Fault
LABEL EQUIPMENT AND TRAIN PERSONNEL

Arc Flash Studies -
Develop Model
Analysis
Recommendations
Labels
Training
DANGER

ELECTRIC ARC FLASH HAZARD

Will cause severe injury or death.

Turn OFF ALL power before opening. Follow ALL requirements in NFPA 70E for safe work practices and for Personal Protective Equipment.
WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

| 24 inch  | Flash Hazard Boundary          |
| 3        | cal/cm² Flash Hazard at 18 inches |
| 1DF      | PPE Level, 1 Layer 6 oz Nomex®, Leather Gloves, Faceshield |
| 480 VAC  | Shock Hazard when Cover is removed |
| 36 inch  | Limited Approach               |
| 12 inch  | Restricted Approach - 500 V Class 00 Gloves |
| 1 inch   | Prohibited Approach - 500 V Class 00 Gloves |

Equipment Name: Slurry Pump Starter

- Provides guidance for the calculation of incident energy and arc flash protection boundaries.
- It presents formulas for numerically quantifying these values.
- The IEEE 1584 Guide also includes an Excel Spreadsheet “Arc-Flash Hazard Calculator” which performs the actual calculations using the formulas stated in the Guide.
Personal Protective Equipment (PPE)

- Cumbersome
- Hot
- Reduces Mobility
- Increases Fatigue
LABEL EQUIPMENT AND TRAIN PERSONNEL

Personal Protective Equipment (PPE)

Much Better!
SOLUTIONS THAT REDUCE ARC FLASH INJURIES and DAMAGE

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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.
MINIMIZE RISK WITH GOOD SAFETY PRACTICES

Bad – Exposed Back of Neck

Good – All of Body Protected
SOLUTIONS THAT REDUCE ARC FLASH INJURIES and DAMAGE

• Label Equipment & Train Personnel
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REDUCE AVAILABLE FAULT CURRENT

- Lowering fault current does not always lower Incident Energy
- Fuse vs Breaker
- No one single answer
- Must Do Arc Flash Study
REDUCE AVAILABLE FAULT CURRENT

- Operate with a Normally Open Tie During Maintenance
- Change Out Transformer – Smaller KVA and/or Higher Impedance
- Add Reactors
- May be Better or Worse with Fuses
- BUT– Complications--
High Resistance Grounding

- HRG Units
- Typically Under 5 Amps
- Pulsing Contactor
- Many Options
- LV or MV
- Does Not Preclude PPE
- Lowers Probability of Accident
SOLUTIONS THAT REDUCE ARC FLASH INJURIES and DAMAGE

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Issues with IEEE 1584 LV Circuit Breakers

- SIMPLE method is based upon “worst case” time of 4 manufacturers time/current curves. VERY conservative!
- ALTERNATE method requires manufacturer specific time/current curve input.
- Concerns with ALTERNATE method too because circuit breaker time/current curves are very conservative in their instantaneous region.
- Neither circuit breaker calculation method accounts for their current-limiting effects.
- Neither based on any actual circuit breaker test data.
# FASTER CLEARING TIMES

## Arc Flash Performance Comparison

### Molded-Case Circuit Breakers

<table>
<thead>
<tr>
<th>Model Description</th>
<th>Incident Energy at Bolted Fault Current</th>
<th>IEEE 1584 Generic Equation</th>
<th>IEEE 1584 Using Time Current Curve Input</th>
<th>Tested Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>225 A MCCB with Thermal-Magnetic Trip Unit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolted fault current</td>
<td>Min: 3.4 kA, Mid: 35 kA, Max: 100 kA</td>
<td>N/A¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inc. Energy via IEEE 1584 Table E.1 <strong>Generic</strong> (Cal/cm²)</td>
<td>N/A¹, 1.7, 4.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inc. Energy via IEEE 1584 &amp; <strong>Trip Curve</strong> (Cal/cm²)</td>
<td>59.6, 1.1, 2.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Measured</strong> Incident Energy (Cal/cm²)</td>
<td>0.08, 0.1, 0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1200 A MCCB with Electronic Trip Unit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolted fault current</td>
<td>Min: 20 kA, Mid: 35 kA, Max: 100 kA</td>
<td>N/A¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inc. Energy via IEEE 1584 Table E.1 <strong>Generic</strong> (Cal/cm²)</td>
<td>N/A¹, 3.5, 9.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inc. Energy via IEEE 1584 &amp; <strong>Trip Curve</strong> (Cal/cm²)</td>
<td>218, 3.5, 5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Measured</strong> Incident Energy (Cal/cm²)</td>
<td>1.86, 1.2, 1.64</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ N/A = Not Applicable because it is outside the range of the IEEE 1584 Generic Equation
LV Power Circuit Breakers

- Unless a Low Voltage Power Circuit Breaker operates in the Instantaneous trip mode, the arc flash energy values will require Category 3 PPE or greater.

- Zone Selectively Interlocked Circuit Breakers provide significantly lower Arc Flash energy values:

  Testing confirms Circuit Breakers (4000A maximum) require Category 2 PPE (8 cal/cm²) with proper instantaneous settings.

- During maintenance it is recommended to temporarily adjust the Instantaneous and Ground Fault (if available) trip settings to their lowest value.
FASTER CLEARING TIMES

Zone Selective Interlocking

Without ZSI = 0.5 S:
43.7 Cal/cm²
Greater than Cat. 4 PPE
DANGER!

With ZSI = 0.08 S:
7.0 Cal/cm²
Cat. 2 PPE
FR Shirt & Pants

35kA fault current

SD= 0.5S
SD= 0.3S
SD= 0.3S
SD= 0.3S
FASTER CLEARING TIMES

Zone Selective Interlocking – Example

- An Off-Shore Oil Platform in the Gulf of Mexico lowered their incident energy exposure from 85 Calories down to 12.7 Calories by retrofitting their 480 V Swgr with ZSI.
FASTER CLEARING TIMES

High Speed Clearing
Bus Differential 87B
FASTER CLEARING TIMES

Arcflash Reduction Maintenance Switch™

- Door Mounted Components
- Breaker Mounted Components

Components:
- Breaker Mounted Components
- Harness
- DIGITRIP
- Arcflash Reduction Maintenance Switch
- Indicating Light
- Lockout Switch
- Battery
FASTER CLEARING TIMES

Arcflash Reduction Maintenance Switch™

An external over-ride switch and circuitry are connected to a breaker’s trip unit, and is adjustable between 2.5X - 10X.

When a person wants to perform maintenance, they close the switch, which automatically over-rides all of the delay functions, and causes the breaker to trip without any intentional delay whenever a fault is detected. Use its lockout features for normal lockout – tag-out procedures.
Upon completion of the maintenance, the lock is removed, the switch is manually opened, and all previous trip unit settings are again re-activated, without need for recalibration.
Arcflash Reduction Maintenance Switch Example

- High Avail Fault Current
- Standard Breaker vs. Arcflash Reduction Maintenance Switch
- Normal settings – HRC=3 (10.7 cal)
- With Arcflash Reduction Maintenance Switch HRC=1 (2.2 cal)
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
FASTER CLEARING TIMES

Substations Without Main Secondaries

- Any Exposure / Racking Feeder Breakers – Must be Cleared by Primary Fuse
- 100 Calorie Exposure
FASTER CLEARING TIMES

Substations Without Main Secondaries

MiniVac Primary Switch Retrofit

**BEFORE**
- 1200A
- 61KA
- CLE 100E
- 1500 KVA
- 1600AF/1200AT

**AFTER**
- 1200A
- 61KA
- MiniVac
- 1500 KVA
- 1600AF/1200AT

**Fault at 480V Switchgear Bus**
- 31.8kA Symmetrical Fault current
- 1167°F AF Boundary
- 702.4 cal/cm @ 18°C
- NFPA70E-2004: Category 4 is highest category @ 40 cal/cm

**MiniVac Retrofit**
- 600A or 1200A
- 1200A
- 1600AF/1200AT
- 1600AF/1200AT
- 1600AF/1200AT

**Fault Downstream of LVPCE**
- 31.8kA Symmetrical Fault current
- 22.2°F AF Boundary
- 1.8 cal/cm @ 18°C
- NFPA70E-2004: Category 0
FASTER CLEARING TIMES

Substations Without Main Secondaries

- Retrofit Primary Fuse with Mini Vac Bkr
- Sense at 480V Txmr-Trip Primary
- Use Group Settings for ARMS
- Many Variations
- Must Meet ANSI C37.59
FASTER CLEARING TIMES

Powercon Fused Load-Break Switch Retrofit
Installed at Weyerhaeuser Springfield OR During Sept 2006 Outage
E-ESS ACE installed 600A, 40kA VCP-T with 530MV trip unit

Weyerhaeuser Springfield: Before

Weyerhaeuser Springfield: After
FASTER CLEARING TIMES

Powercon Fused Load-Break Switch Retrofit
Installed at Weyerhaeuser During Sept 2006 Outage
E-ESS ACE installed 600A, 40kA VCP-T with 530MV trip unit

ML750 supplied/installed by Weyerhaeuser

The best design choice:
600A 40kA VCP-T with integral 520MC trip
connected to secondary Magnum sensor (>12ft)
Lower cost 50/51 primary protection – DT3000
SOLUTIONS THAT REDUCE ARC FLASH INJURIES and DAMAGE

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Remote Racking of MV Breakers

Remain physically outside the flash protection boundary. Therefore NO ARC FLASH HAZARD protection required!
MOVE PEOPLE FURTHER AWAY

Remote Power Racking

VS.

VS.
MOVE PEOPLE FURTHER AWAY

Remote Switching: Chicken Switch

- Without

- With
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REDIRECT BLAST ENERGY

Arc-Resistant Switchgear

Redirects Arc Energy and Particulates
MOVE PEOPLE FURTHER AWAY

5/15 kV Arc Construction

Arc Flaps

Control Section

VT drawer

1200A can be 1 high or 2 high

Manual Close/Open Push Buttons

2000A or 3000A breaker with Vent
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PREVENT FAULT

Equipment Designed for Safety

Arc Safe MCC Bucket
Minimum exposure to energized parts
PREVENT FAULT

Bucket Position
- Connected
- Test
- Withdrawn

Handle Mechanism

Device Island
- Start, Stop, Auto, Man

Breaker

Starter

Racking Tool Receiver

Unit Latch

Internal Shutter Position
- Open
- Closed
PREVENT FAULT

Monitor Transformer Bushings

• Power Factor
• Capacitance
PREVENT FAULT

Monitor Insulation Integrity

- Switchgear, Generators, Motors
PREVENT FAULT

Results of Partial Discharges

Phase to Phase Discharges on Ring Bus – 49 MVA Generator
PREVENT FAULT

Infrared Scanning Windows for LV/MV Assemblies
PREVENT FAULT

Continuous Thermal Monitoring

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