Arc-Flash Mitigation

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Why Is Arc Flash Important?

“There are 10 OSHA-reportable arc-flash incidents involving more than one fatality every day in the USA.”
– Electric Energy Online

“There are one or two deaths per day from these multitrauma events.”
– Dr. Mary Capelli-Schellpfeffer
What Is Arc Flash?

- Dangerous condition associated with release of electrical energy
- Arc-flash energy: proportional to $V \cdot I \cdot t$

Arc-Flash Calculations

- NFPA 70E-2004 – basis for PPE
- IEEE 1584
  - Lee method – over 15 kV
  - Microsoft® Excel® spreadsheets
- Incident energy measured in $J/cm^2$
Speed Up Detection

- Coordination time adjustment with existing relays
- Differential schemes
- Fast bus trip schemes
- Instantaneous overcurrent elements during maintenance
- Arc-flash detection with light and current
“A” is the downstream relay with the longest time delay

Change Settings if Coordination Allows
### Adjust Overcurrent Relay Trip Times

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Trip Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing relay use</td>
<td>Possible coordination issues</td>
<td>0.5 to 2 s</td>
</tr>
<tr>
<td>Small improvement in trip time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### High-Impedance Bus Differential Relays

![Diagram of High-Impedance Bus Differential Relays]

- Pickups:
  - 2000 V
  - 400 V
  - 80 V
  - 0 V

- 87Z module
High-Impedance Bus Differential Relay Scheme Analysis

<table>
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<tr>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Trip Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>Additional relay, wiring, and dedicated CTs</td>
<td>&lt; 24 ms</td>
</tr>
<tr>
<td>Secure</td>
<td>Complexity</td>
<td></td>
</tr>
</tbody>
</table>

Low-Impedance Bus Differential Relays
# Low-Impedance Bus Differential Relay Scheme Analysis

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<td></td>
</tr>
<tr>
<td></td>
<td>Possible CT saturation</td>
<td></td>
</tr>
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</table>

## Fast Bus Trip Scheme

Digital Communications
## Fast Bus Trip Scheme Analysis

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Trip Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost</td>
<td>More relay settings</td>
<td>&lt; 30 ms</td>
</tr>
<tr>
<td>Fast</td>
<td>CTs on bus side of feeder result in delayed tripping</td>
<td></td>
</tr>
<tr>
<td>Secure</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Maintenance Switch

Control switch enabled instantaneous element only during maintenance
Instantaneous Trip Scheme Analysis

<table>
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<th>Disadvantages</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>Loss of coordination</td>
<td>&lt; 24 ms</td>
</tr>
<tr>
<td>Low cost</td>
<td>Switch may be left on</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Does not detect fault current below instantaneous setting</td>
<td>Does not trip</td>
</tr>
</tbody>
</table>

Combined High-Speed Light and Overcurrent Sensing

- Fault Current
- Arc-Flash Overcurrent
- Arc Flash
- Arc-Flash Light Sensors (up to 4)
Relay + AFD = Most Reliable and Economical Solution

Fault Current

Bare-Fiber Loop

Point Sensors

Loopback Test

Snap-In Mounting

Wide-Angle, Arc-Flash Point Sensor
Sensors Report Before They Melt

- **Light Intensity**
- **Phase Current**

Sensor Installation in Switchgear

- 15 kV, 1,200 A, Air Magnetic
Sensor Mounting Locations

Avoid Breaker Track System
Breaker Compartment
Mount on Back of Section

Outgoing Line Compartment

Install Point-Sensor Assembly

Dual V-Pin Latch
Jacketed-Fiber Zipcord Duplex

V-Pin Terminators

Sensor

01–35 Meters
Best Locations Have Fault Source Visibility

Best | Good | Suboptimal
Install Bare-Fiber Assembly

Jacketed Fiber

Splice Bushing

Bare Fiber

Up to 50 Meters

Up to 30 Meters

Jacketed Fiber      Connector Splice Bushing      Bare Fiber

Transition Jacketed-Fiber to Bare-Fiber Sections

ST® Connection Example

5/29/2015
Bare-Fiber Mounting in Bus Section

Bare-Fiber Mounting on Top
**Time-Overlight™ Improves Security**

- Ultra-fast overcurrent
- Analog-measured light intensity
- Combined for fast and secure protection

**Overcurrent AND Flash Detection Scheme Analysis**

<table>
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<tr>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Trip Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fastest trip</td>
<td>Mounting sensors</td>
<td>As fast as 2.5 ms</td>
</tr>
<tr>
<td>Secure with current AND flash detection</td>
<td>Additional testing</td>
<td></td>
</tr>
<tr>
<td>Low cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordination maintained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous monitoring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MCCs Have High Arc-Flash Hazards

• Dangerous condition associated with release of energy
• Arc-flash energy is proportional to $V \cdot I \cdot t$

Low-Voltage MCC

Magnetic Breaker  Contactor  SEL-849  Motor
Combined High-Speed Light and Overcurrent Sensing

- Built-In CTs
- Arc-Flash Overcurrent
- Built-In Arc-Flash Light Sensor
- Arc Flash

Motor

Arc Flash and GOOSE Messaging

Electrically Operated Breaker Equipped With Shunt Trip Coil

SEL-751A

MCC Bucket

SEL-449

AFD Sensor

DC Supply

SEL-751A Logic

Arc Flash Detected Through GOOSE Light Detected by the Loop Sensor

OUTxx

OutType

High-Speed Output Contact: Trip to 480 V SWGR Breaker

Arc Flash Detected Send GOOSE Message
Reduction Scheme Comparison

Incident Energy (cal/cm²)

Flash Boundary (m)

Original Scheme

Fast Bus Trip

Instantaneous Trip

Arc-Flash Detection

Incident Energy Reduction

Arc-Flash Detection Reduces Incident Energy

Switchgear Test

PPE Test

Without AFD

With SEL AFD

Hazard/Risk Category

Better
Reduce Arc-Flash Hazards

• Arc-flash hazards are real and need to be addressed

• Protection solutions are already in place to address issues
  ♦ Maintenance switch
  ♦ Fast bus trip schemes
  ♦ Bus differential schemes
  ♦ Overcurrent AND arc-flash detection

Questions?