Hidden Risks of Aging Electrical Systems
Agenda

- What Is That Grey Box?
- Electrical Equipment Life Expectancy
- Electrical Equipment Life Risk Factors
- Arc Flash Awareness
- Potential Mitigation Actions
Electrical Systems Are Vital But Often Unrecognized Infrastructure

- What are those grey boxes anyway?
Improper Uses of Electrical Equipment Rooms

• Lack of recognition and respect of electrical equipment has risks
Electrical Equipment Life Expectancy
How Long Does Electrical Equipment Last?

Component Life Cycle Reliability

Predicted Failure Rate

Bathtub Curve

Infant Mortality

Level Period of Reliability

Wear Out

New Component

Aged component

Time
## Typical Electrical Equipment Life Expectancies

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>EXPECTED USEFUL LIFE, YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitors</td>
<td>17</td>
</tr>
<tr>
<td>LV molded case circuit breakers</td>
<td>20</td>
</tr>
<tr>
<td>LV power circuit breakers</td>
<td>15 - 20</td>
</tr>
<tr>
<td>MV power circuit breakers</td>
<td>15 - 20</td>
</tr>
<tr>
<td>MV vacuum circuit breakers</td>
<td>15 - 20</td>
</tr>
<tr>
<td>Dry-type transformers and reactors</td>
<td>20</td>
</tr>
<tr>
<td>Liquid filled transformers</td>
<td>30</td>
</tr>
<tr>
<td>LV and MV cables</td>
<td>20</td>
</tr>
<tr>
<td>Protective relays</td>
<td>Not stated</td>
</tr>
<tr>
<td>Motors and motor starters</td>
<td>20 - 30</td>
</tr>
<tr>
<td>VFDs and UPSs</td>
<td>20</td>
</tr>
</tbody>
</table>

Reference IEEE Gold Book

*(Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems)*
Can Electrical Equipment Operate Reliably Beyond Normal Life Expectancy?

- Regular maintenance, optimal loading, and clean environment can extend equipment life.

Administration Building
Downtown Raleigh
1966 Westinghouse
Low Voltage Switchgear
Aging Electrical Infrastructure Risks

- Reduced equipment reliability
  - Equipment operating at available fault levels exceeding equipment rating
- Equipment damage & personnel injury
  - Unrecognized hazard or hazard greater than anticipated
  - Electrical shock, electrocution, or arc flash
- Unscheduled outages
- Financial costs of emergency repairs, rental equipment, regulatory fines, and liability awards

- Yes, it is still in operation!

Risks are unfortunately not realized until actual failure occurs.
Data Centers Electrical Outage Financial Impact

Ponemon Institute 2013-2016 Survey: Cost of Data Center Outages

Greatest root cause of unplanned data center outages?
- UPS system equipment failure
Electrical Equipment Life Risk Factors
Aging Electrical Equipment Failure Causes

- Utility available fault current changes
- Excessive loading, harmonics, surges
- Inadequate documentation
- Improper operation under current electrical codes, standards, regulations
- Lack of preventative maintenance
- Environmental degradation

• Electrical equipment asset management should be a priority for facility owners.
OSHA 46 CFR 183.210
Protection From Wet/Corrosive Environments

- Electrical equipment use in the following spaces must be dripproof:
  - Machinery spaces
  - Space exposed to splashing, washdown
- Electrical equipment exposed to weather must be watertight
- Electrical equipment exposed to corrosive environments must be of suitable construction and resistant to corrosion

• Rainproof?
Corrosion Coupon Measurements

Prior to installation
After 7 Days
After 30 Days
After 60 Days
Example Adverse/Corrosive Contaminants

- Hydrogen Sulfide
- Sulfur Dioxide
- Ammonia
- Chlorine
- Chlorinated Compounds
- Salts
- Moisture/Water

Corrosion is *accelerated* by increased concentration of contaminants, elevated temperature and high humidity.
Components/Wiring Internal To “Protected” Enclosure

- Internal corrosion conditions occur undetected unless routine inspections are implemented
Silver Plated Terminals/Bus

Corrosion can affect protective equipment clearing time including “no trip” failure mode
How Many Installations Are Gambling Upon “Wear Out” Time?

- Affects of high ambient temperatures, humidity, corrosion, and lack of maintenance upon hastening end-of-life.

24 March 2016
Arc Flash Video - Molten Metal, Intense light
Arc Flash Basics

An arc flash produces shock wave, molten metal, intense light, and heat exposure.
Arc flash Examples – Shock Wave, Molten Metal, Intense Light, Heat
Calculating Arc Flash Incident Energy

- Incident Energy based on:
  - Available fault current
  - Protective device clearing time
  - Working distance away from the equipment

- Accurate available utility fault current level and actual protective device settings are critical.
### Personal Protective Equipment (PPE)

<table>
<thead>
<tr>
<th>Hazard/Risk Category</th>
<th>Arc-rated long-sleeve shirt</th>
<th>Arc-rated pants or overall</th>
<th>Arc-rated face shield with hard hat</th>
<th>Safety glasses</th>
<th>Hearing protection</th>
<th>Leather &amp; voltage rated gloves (as needed)</th>
<th>Leather work shoes</th>
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</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Arc-rated long-sleeve shirt</td>
<td>Arc-rated pants or overall</td>
<td>Arc-rated face shield &amp; balaclava or</td>
<td>Arc flash suit with hard hat</td>
<td>Safety glasses, Hearing protection</td>
<td>Leather &amp; voltage rated gloves (as needed)</td>
<td>Leather work shoes</td>
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<tr>
<td><strong>2</strong></td>
<td>Arc-rated long-sleeve jacket</td>
<td>Arc-rated pants</td>
<td>Arc-rated flash hood with hard hat</td>
<td>Safety glasses, Hearing protection</td>
<td>Leather &amp; voltage rated gloves (as needed)</td>
<td>Leather work shoes</td>
<td></td>
</tr>
<tr>
<td><strong>3</strong></td>
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80% electrical injuries are **burns** from exposure to arcing fault.
Improperly Installed or Maintained Equipment May Increase OCPD Fault Clearing Time

\[ E_{MB} = D_B \times t_A \times F \]

Where:
- \( E_{MB} = \) incident energy
- \( D_B = \) distance from arc
- \( t_A = \) arc duration, seconds
- \( F = \) fault current (thousands)

Example:
- 5 cycle (0.083 secs) \( t_A = 3.5 \text{ cal/cm}^2 E_{MB} \)
- 30 cycle (0.5 secs) \( t_A = 25 \text{ cal/cm}^2 E_{MB} \)

• “PPE selection based upon incident energy analysis may not provide adequate protection from actual arc flash hazard.” NFPA 70E Section 130.5
OSHA estimates on average, **74 fatalities and 444 serious injuries** occur annually among employees performing work involving electric power generation, transmission, and distribution.

**2,000 workers** – number admitted annually to burn centers for extended injury treatment from arc fault energy exposure

Reference IEEE Report
Governing Arc Flash Regulations and Standards

- OSHA Standards 29 Code of Federal Regulations,
  - Part 1910 General Industry
  - Part 1926 Construction Industry
- NFPA 70 - The National Electrical Code (NEC)
- NFPA 70E (2012) - Standard for Electrical Safety in the Workplace

• Arc flash regulations apply to existing facilities not just new construction
NCDOL adopted 29 CFR 1910 effective October 8, 2014
**Federal Civil Penalties**  
*Inflation Adjustment Improvements Act of 2015*

**Maximum allowable penalties for OSHA citations:**

<table>
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<th>Prior to 2016</th>
<th>Effective 2016</th>
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<td>Other Than Serious</td>
<td>$1,000</td>
</tr>
<tr>
<td>Serious</td>
<td>$7,000</td>
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<tr>
<td>Willful</td>
<td>$70,000</td>
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</table>

* OSHA penalties now indexed (CPI) for inflation
All employers shall be responsible for:

- **Risk Assessments to Employees** no later than January 1, 2015
- **Electrical Hazard Classification** no later than April 1, 2015
- **Personal Protective Equipment** no later than April 1, 2015
- **Host – Contract Employer Responsibilities**
- **Information Transfer/Minimum Documentation**

Amongst Affected Industries Include **Educational Facilities and Hospitals** Federal Register 4/11/2014
Potential Mitigation Measures
Implement Electrical Asset Management Program

- Identify installation age
- Collect O&M info
- Regular inspection
  - Signs of arcing or flash
  - Search broken parts, loose hardware (e.g. bolts on the floor)
- Cleaning and lubricating
- Confirm anchorage, alignment, grounding

- Confirm organizational maintenance philosophy and contract for those tasks designated as undesirable
Consider Thermal Inspection Program

Remove and replace equipment from service based upon infrared scan results
Implement Inspection and Maintenance Program

“Circuit breakers should be cycled ON-OFF at least every 6 months” – ANSI/NEMA AB 3
Corrosive Environment Mitigation
Example 1 of 2

Where unable to locate electrical equipment in “clean” areas then consider mitigating corrosive gas penetration

24 March 2016
Corrosive Environment Mitigation
Example 2 of 2

Where unable to locate electrical equipment in “clean” areas then consider mitigating corrosive gas penetration
Replace Recalled and Legacy Equipment

• “Do not reclose…current could flow through the ‘OFF’ breaker…”
Upgrade In Place
Aging and Obsolete Electrical Equipment

- Economical upgrade for older switchgear
- Modernizes circuit breaker technology
- New operating and racking mechanisms
- Improved electrical system reliability

Passive components (bus, terminals, structure) remain while replacing active components
Optional Electrical Accessory Enhancements

Infrared viewing windows and remote breaker operating/racking mechanisms
Prominently Post Accurate Documentation Records

- Commit to maintaining documentation accuracy subsequent to future modifications
Commit to Implementing Arc Flash Hazard Awareness

- Target new employees as well as frequent refresher sessions scheduled regularly for all personnel.

- Clearly identify “qualified” and “non-qualified” personnel.

- Keep arc flash hazard analysis up to date with system modifications and utility changes.
• >80% electrical facilities exceed 20 years of installation age
• <25% electrical facilities exceed 25 years of installation age
Considerations for Addressing Aging Electrical Infrastructure Systems

- Implement asset management program w/ electrical system focus
- Establish regular preventative maintenance program
- Maintain arc flash hazard analysis & protective device study
  - Update with system changes or service utility changes
- Maintain accurate system documentation
- Monitor electrical equipment environment
- Consider enhanced accessories: infrared windows, remote racking

• Continuing to ignore the risks of aging electrical infrastructure should no longer be accepted practice!

24 March 2016
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• State Construction Office
  • Matthew Marbois
  • (919) 807-4099
  • matthew.marbois@doa.nc.gov
Thank You!
# References

<table>
<thead>
<tr>
<th>Slide 6 - Bathtub Reliability Curve</th>
<th><a href="http://www.thereliableboat.com">www.thereliableboat.com</a></th>
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<tr>
<td>Slide 16 – Photograph</td>
<td>EC&amp;M Magazine “What’s Wrong Here-Hint: Rotten to the Core”, Nov 2015</td>
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<tr>
<td>Slide 20 - Video</td>
<td><a href="http://www.youtube.com">www.youtube.com</a></td>
</tr>
<tr>
<td>Slide 21 - Image</td>
<td><a href="http://www.arcflash-training.ca">www.arcflash-training.ca</a></td>
</tr>
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</table>
| Slide 22 – Photographs            | www.huntelectric.com    
                                   | www.cablejoints.co.uk |
| Slide 24 – Chart                  | www.powerhawke.com      |
| Slide 25 – Image                  | www.schneider-electric.com |
| Slide 33 – Photographs            | www.martechnical.com    |
| Slide 35 – Photographs            | Water and Sewer Authority of Cabarrus County North Carolina |
| Slide 38 – Photographs            | www.schneider-electric.com |
| Slide 39 – Photographs            | www.eaton.com           |