Electrical Failure Investigations

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Forensics, the Mystery

• Our Forensics Work

• Project Examples
Why Do Things Fail?
Because of...

- Installation
- Application
- Operation
- Maintenance
What we will look at...

- When the installer does it wrong...
- When the unexpected happens...
- When the design has problems...
- When People get involved...
First:

Poor Installation...
A High Voltage Bushing

- 27 KV bushing installed on a commuter train system.
- Steamed and Smoked when energized.
- Client wanted to know: What happened.
Manufacturer’s Information

- Cut the Cable
- Strip off insulation
- Strip away insulation shield
- Wrap tape stress cone
- Attach top connector
- Assemble components
- Fill with sealant
The first step: X-ray the Sample
What the X-ray revealed:

- The connector had not been properly soldered.
- The conductor strands were clearly visible.
How bad was the connection?
It was not the only problem!

• Question: Where did the steam come from?
• Further investigation showed a second problem.
The cable seal was improper.

The seal is in the wrong place.
The Correct Seal Position

The seal is against the outer jacket material.
The Report:

• The poor connection caused heat and steam.
• The improper seal allowed water to penetrate the bushing.
• This was caused by poor workmanship.
Next Example:

Contractor: “It’s bad equipment!”

Manufacturer: “Poor workmanship!”

Owner: “Help!”
Arcing between phases
Conclusion:

• Improper installation
Let’s take another example..

“Well, we had a limited budget...”
Conclusion:

- Mismatch of equipment
- Poor installation
Weird ones:

Something “Off the Wall”...
An Airport Maintenance Facility in Texas
The Problem:

- Blow-outs between A Phase and Ground
- Several in the first months of installation.
- No previous history of such faults.
- Was it bad product?
- Was it bad installation?
- What was the cause?
Power Bus Duct

- Reduced impedance.
- Reduced cost.
- Increased inherent strength.
- Manufacturing simplicity.
- Reliable.
Buss Duct End View
Insulation Porosity
The Report:

- Rain water entered the product.
- Insulation porosity was present.
- The installation was correct.
- The product was properly produced.
- The transportation was incorrect.
Another weird one:

A defective product.

Undetected, until suspicions were aroused.
The Problem:

- The installing splicers did not like the cable.
- Client wanted it tested to Specifications.
5 KV Cable Sample
Suspicious gaps in the strand shield system.
Close-up of the defect.

- The strand shield had separated during extrusion.
- The mark did not follow the strands.
- A longitudinal impression was present.
The Culprit

- A cut-off knife caused the gash in the conductor stranding.
The Report:

- A manufacturing defect was found.
- The life of the cable had been shortened.
- The manufacturer offered the client an extended warranty.
–A Different Type of Case:
–A Critical Area—EDP
–The Fuse Blew!
–The mystery…

There was no fault!
Intact Elements
Mechanical Fractures
Hey, wait a minute...

- Earlier testing records noted this fuse--
  - One fuse had high resistance
  - Replacement had not been done
Conclusion:

- Work hardened elements fractured
- Fuse opened on less than full load

- Operation and Maintenance Issue
- Preventable Outage
TIME OUT!

How do you know that?
The Forensic Process...

- Things we know:
  - Arc Behavior
  - Fire Directions
  - Expected Performance

- Things we Learn:
  - Circuit Loading
  - Environmental Factor
  - Discovery
    - Inspection
    - Testing
The Fault Tree

- Initiating Event
- Failure Mechanism
- Findings
  - Test, inspections, measurements
- Conclusion:
  - Not Likely Cause
  - Most Probable Cause
# Fault Tree for Busway Failure at Joint Stack

(Applicable to 1UDP 7-1)

<table>
<thead>
<tr>
<th>Initiating Event</th>
<th>Failure Mechanism</th>
<th>Findings</th>
<th>Comments and Observations</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Loose joint stack connection causes localized heating</td>
<td>Insulation failure due to high temperature</td>
<td>This section of busway was carrying no load. No evidence of discoloration of conductors from overheating.</td>
<td></td>
<td>Not a likely failure mechanism.</td>
</tr>
<tr>
<td>2. Improper assembly - inadequate penetration of joint stack into bus bars resulting in inadequate contact surface which causes localized heating</td>
<td>Insulation failure due to high temperature</td>
<td>This section of busway was carrying no load. No evidence of discoloration of conductors from overheating.</td>
<td></td>
<td>Not a likely failure mechanism.</td>
</tr>
<tr>
<td>3. Improper assembly - inadequate penetration of joint stack into bus bars resulting in inadequate overlap of insulation materials</td>
<td>Insulation failure due to overstress of air dielectric</td>
<td>Marks on conductors indicate only 0.5 inch of conductor overlap, leaving about 0.25 inch of exposed conductor on each phase and ground.</td>
<td>If properly installed, no portion of the conductor should be exposed. Failure occurred at this location. The NEC and UL 857 require an air space of at least 1 inch between uninsulated conductors.</td>
<td>Most probable cause of failure - especially if in combination with contamination (4).</td>
</tr>
<tr>
<td>4. Water, contamination, animal or insect contact.</td>
<td>Insulation failure</td>
<td>Cover plates are not dust tight. Small amounts of dust and dirt were found.</td>
<td>Exposed conductors as considered in 3 above would be more susceptible to contamination than properly assembled busway and connections.</td>
<td>Possible failure mechanism. More likely combined with improper assembly (3).</td>
</tr>
<tr>
<td>5. Transient or other overvoltage.</td>
<td>Insulation failure</td>
<td>No transient overvoltages were identified during voltage monitoring performed by Walsh, Higgins personnel.</td>
<td>Exposed conductors as considered in 3 above would be more susceptible to overvoltage than properly assembled busway and connections.</td>
<td>Not a likely failure mechanism.</td>
</tr>
</tbody>
</table>
A Design Problem:

• “Well, I’m not sure what the load is...”
Why did it fail?

Better question: What is it?
Conclusion:

• Bus Overload
  – 4000 Amp Bus
  – 5000 Amp Load!

  – Application
And then:

The Human Factor...
What People will do...

- Working “Hot”
“I don’t need no stinking safety procedures.”

“Hey, loan me your wiggie.”
Conclusion:

- Defective meter initiated fault
- Poor Work Practices
- Lack of Protective Equipment
But we paid extra to keep the power **on**!

(Human Factor)
The Attorney's Office
480 Volt Generator
208 Volt Generator
Conclusion:

- Improper wiring of generator
  - No connected neutral or ground
  - Metal Oxide Varistor could not withstand the voltage.
  - Fire was result
When maintenance goes wrong...

“What’s this green wire for?”

“It’s only a street light!”
Conclusion:

• Poor Installation and Maintenance:
  – Water Damage
  – Pinched Wire
  – Not Grounded

• Child’s death:
  – She touched the energized light pole and a grounded fence.
In Summary:

• Forensics finds the strangest things.
  – Poor Workmanship
  – Defective Product
  – Off-the-Wall Problems