Understanding Touch Voltage Potential Risk Due to Tree-to-Conductor Contact on Distribution Circuits

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Principle Investigators:
J.W. Goodfellow & D. Crudele

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Touch Potential Contact Voltage

An investigation in to Step and Touch Voltages Potentials Created by Incidental Tree-to-Conductor Contacts on overhead distribution lines.

Incidental Tree-Conductor Contacts

It is common for 10% of the trees to have made incidental contact with energized distribution conductors prior to scheduled maintence pruning.

So called "burners" are the result of high impedance faults leading to desiccation and wilting of foliage.

If incidental contact is less of a reliability issue than we have assumed, what else must be considered?

- Mechanical mode of failure.
- Cost of PM.
- Public Safety.
  - ***Touch potential***
  - ***Step potential***
  - ***Fires?***

Test Trees

Pin Oak

Silver Maple

Mature, open grown, full crowned specimens. Tests conducted in September when the trees were in full leaf. Test site courtesy of Davey Tree, Kent, OH

Tree Structural Form: "Excurrent" vs. "Decurrent"

Pin Oak

Strong central leader, small branch to stem diameter ratio.

Silver Maple

Co-dominant leaders. Large diameter branches.

Specimen Preparation: Concentric Equipotential Ring

- Aluminum nails driven half their length. Pierce bark and well in to wood.
- Nails tied together with light sizing wire wrapped snugly against bark

Specimen Preparation: placement of equipotential rings

A series of rings were established:

- Lowest ring height at root flair.
- Rings spaced by 25 cm to 1.5 meters.
- Upper rings at 2.5 & 3.5 meters above ground.
- Voltage measurements were made between rings.

Simulated Touch Contact With Tree

- Copper mesh pressed against stem.
- 1980 Ω resistor used as surrogate for the human body.
- Placed between 1.25 – 1.5 meter rings.

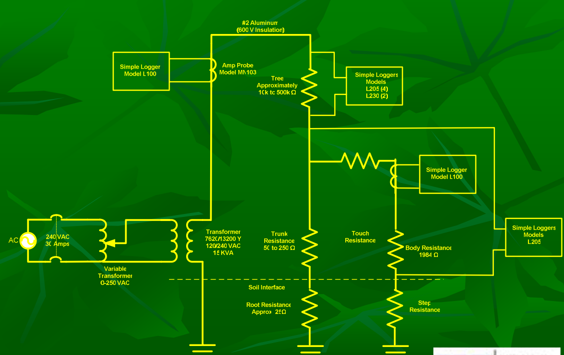
Simulated Touch Contact With Soil

- Galvanized plate of total area similar to soles of human feet.
- Weighted with blocks to simulate body weight of human.

Simulated Conductor Contact

- Short piece of #4ACSR conductor suspended by PVC plastic pipe frame.
- Held lightly in place by gravity and occasionally by light lashing.
- Connected to a 7260V supply.

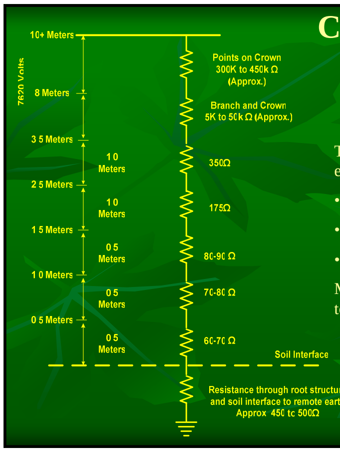
Test Circuit



Individual High Voltage (7620V) Tests Conducted

Test	Species	Description of Contact Location	Fault Pathway Length (m)	Contact Diameter (cm)
1	Oak	Small diameter lateral branch in outer crown	13.67	1.3
2	Oak	Fine twig in outermost crown	14.09	0.6
3	Oak	Secondary branch inside crown	12.19	3.7
4	Oak	Main branch in inner crown, at half way point to main trunk	10.62	4.7
5	Oak	Main branch close to trunk	8.33	8.6
6	Oak	Main branch close to trunk	8.33	8.6
7	Oak	Main stem (trunk) contact	7.00	25.4
8	Oak	Multiple contacts in very small branch tips, outer crown	>13	<1
9	Oak	Multiple contacts in very small branch tips, outer crown	>13	<1
10	Oak	Single small diameter branch, outer crown	>13	0.6
11	Oak	Single branch contact, mid crown	>10	3.8
12	Oak	Single branch contact, mid crown, repeat of test # 11	>10	3.8
13	Maple	Fine twig in outermost crown	11.83	0.4
14	Maple	Small diameter lateral branch in outer crown	11.12	1.5
15	Maple	Secondary branch inside crown	10.26	3.0
16	Maple	Secondary branch inside crown, repeat of test #15	10.26	3.0
17	Maple	Main branch in inner crown, at half way point to main trunk	8.05	4.0
18	Maple	Main branch close to trunk	7.92	6.2
19	Maple	Main stem (trunk) contact	7.00	21.6

Circuit Diagram of a Tree (Silver Maple)



The tree as a series of resistive elements:

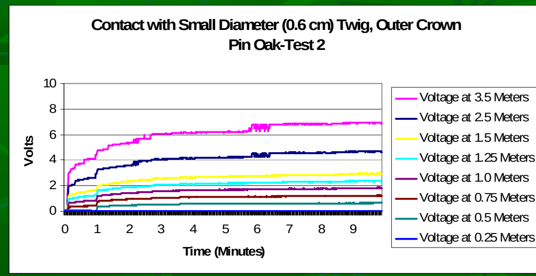
•Fault pathway characteristic vary.

•Diameter is a major factor.

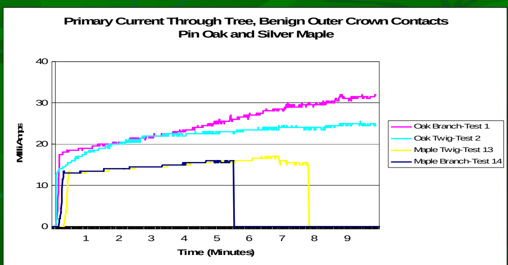
•Distance has an additive affect.

Most of voltage drop occurs close to point of contact.

Contact with Small Diameter Twigs in Outer Crown



Contact with Small Diameter Twigs



Small Diameter Single & Multiple Contacts, Outer Crown

Test	Species	Description of Contact	Max. Voltage @ 1.5 m	Tree Fault Current (mA)	Body Fault Current (mA)
1	Oak	Single contact, branch	<4	32+	<2
2	Oak	Single contact, twig	<3	25	<2
8	Oak	Multiple contacts	<3	-	<1
9	Oak	Multiple contacts	<2	-	<1
13	Maple	Single contact, twig	<5	<17	<1
14	Maple	Single contact, branch	<5	<17	<1

•Simulated contact with multiple small diameter did not increase the observed levels of current and voltage levels.

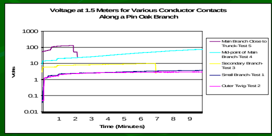
•Body currents were at or below detection limits of the instruments.

Benign Incidental Contacts With Small Diameter Contacts In The Outer Crown

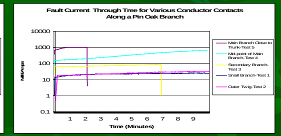
IEEE Standard 80, *"IEEE Guide for Safety in AC Substation Grounding"*, establishes an allowable body current of 164 mA for 30 cycles (0.5min) for a 110 lb person. This same standard establishes allowable touch voltages for a range of soil resistivities. Allowable touch voltages range from 189 V for soils with resistivity of 100 Ω-meters to 410 V for soils with resistivity of 1000 Ω-meters.

The observed levels for voltage within the main stem and current through the tree fault circuit during each test of incidental contacts were well below these allowable levels. The levels of current through the surrogate body circuit were much lower.

Progressively Larger Contacts From Branch Tip To Main Stem



Voltage



Current

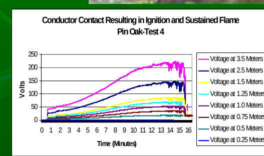
Worst-Case: Contacts With Main Stems

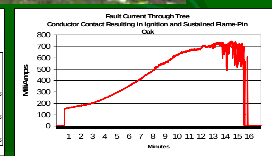
In the test

In the field

The fault pathway involved typically has the largest diameter and shortest pathway length from contact to earth.

Open Flame Contacts





Plans for 2008

- Test additional species:
  - Add other common street tree species.
  - Add a conifer.
- Assess voltage gradients aloft – the potential risk to tree climbers.
- Conduct further work on contact impedance across the bark.
- Investigate impedance across the root-soil interface.
- Conduct tests under wet conditions, simulating precipitation.

For More Information

John W. Goodfellow, BioCompliance Consulting, Inc. jwgoodfellow@msn.com

Dave Crudele, EPRI dcrudele@epri.com