Was the Stray Voltage Really Stray?

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What is Stray Voltage?

- Not presently defined by IEEE 100
- Used extensively in Media
- Two Types Proposed
  - Category 1: Neutral to earth step or touch voltage from normal steady state operation of the distribution system
  - Category 2 : Voltage due to unintentional contact of an energized conductor with a conductive object

What is Stray Voltage?

- This case: Voltage between neutral of the power system and earth
- Convention is V_{ne}
- Measure of Stray Voltage
  - Open Circuit = V_{oc} = voltage seen with high Z voltmeter
  - Closed Circuit = Vne loaded = voltage when an animal or human is in contact between neutral and earth (typically use a 500-1000 ohm load resistor to simulate contact)

What Causes Stray Voltage?

- The neutral carries current and therefore has voltage drop
- Neutral will always be at some voltage relative to earth
- If the voltage is high enough and the source “stiff” enough the body current can be objectionable

What Causes Stray Voltage?

- Primary Cable Neutral Corrosion
- Causes increased V_{ne} due to neutral impedance increase
- Significant Issue with older bare concentric cables (both direct buried and in conduit)

What Causes Stray Voltage?

- Neutral Current Unbalance – creates voltage drop in neutral
- Triplen Harmonics – these currents are additive in neutral – cause voltage drop in neutral
- Perfect 60 hz balance can still have high neutral current when harmonics are present

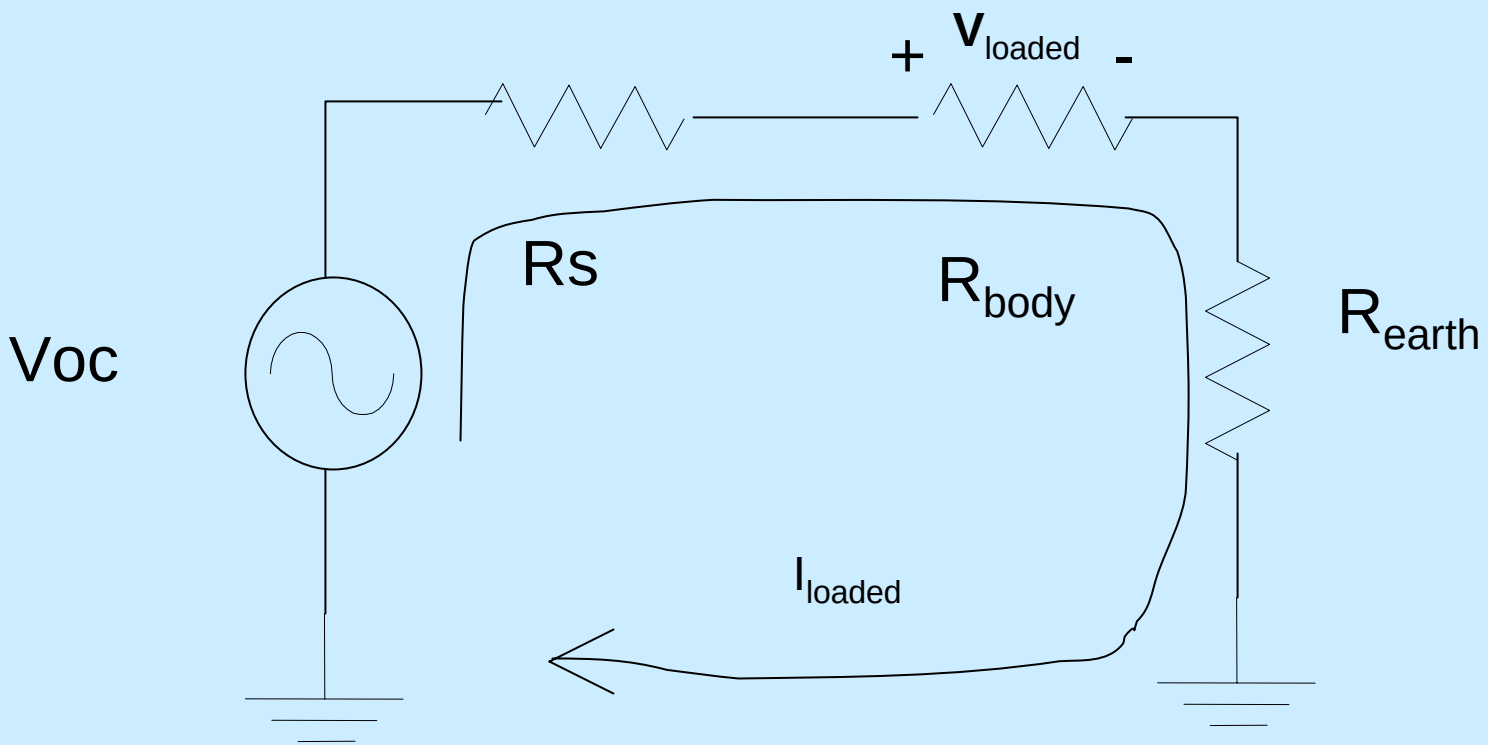
What Causes Stray Voltage?

- Other sources can elevate earth potential relative to the neutral
  - Buried low voltage cable with cuts or bare exposure
  - Nicked street light cables a mile away have been found to energize water pipes and the earth near the pipes

Stray Voltage Hazard Levels

- Determined by Open Circuit vs. Closed Circuit Voltage tests
- How?
- Loaded test allows calculation of maximum current
- Assumes soil resistance is zero
- Uses 500 ohm resistance to simulate body resistance

Stray Voltage Circuit Representation



Calculation Example

- Voc = 26 Volts Vloaded = 16 volts
- Rload = 500 ohms
- I = 16 / 500 = 32 ma
- Rs = (26-16)/.032 = 312 ohms
- Thevinen Equivalent max current

  = 26 / 312 =83 ma

  Assumes no soil resistance

Human Hazard Assessment

- Reference = IEEE 80
- 1ma = Perception Threshold
- 1 – 6 ma = Let Go (unpleasant)
- 9 – 25 ma = No Let Go
  - 10.5 ma for women
  - 16.5 ma for men
- 60ma – 100ma = lethal
- The limits are statistical means for a population and vary with the individual

Where is Stray Voltage a Problem?

- Milking Barns (cows)
  - Milking machine is grounded – cow is standing on earth.
- Swimming Pools
  - entering or exiting pool, humans have simultaneous contact with the deck and pool water, ladders and other fixtures.
  - Showers
    - Human contact with grounded water fixtures while standing on earth (concrete floor) and drain pipes

Stray Voltage Thresholds

- Varies by person and situation
  - Can be affected by source impedance (high Z source produces little current)
- Once sensitized people and animals complain more
- “Let Go” current for 50% of population is 15 ma

Stray Voltage Case Study

Customer experiences shocking in shower

Customer Site Observations

- Customer served from xfmr on dead-end pole
- CATV drop is new cable and not bonded to ground wire at service entrance
- Customer indicated CATV drop replaced about the time shocking started
- Voltage from CATV to neutral was 26 volts!

Check Voltage Levels

- Voc = 26 volts
- Vloaded = 16 volts
- Rload = 500 ohms
- I = (26-10)/500 = 32ma

  = 2 * let go current level

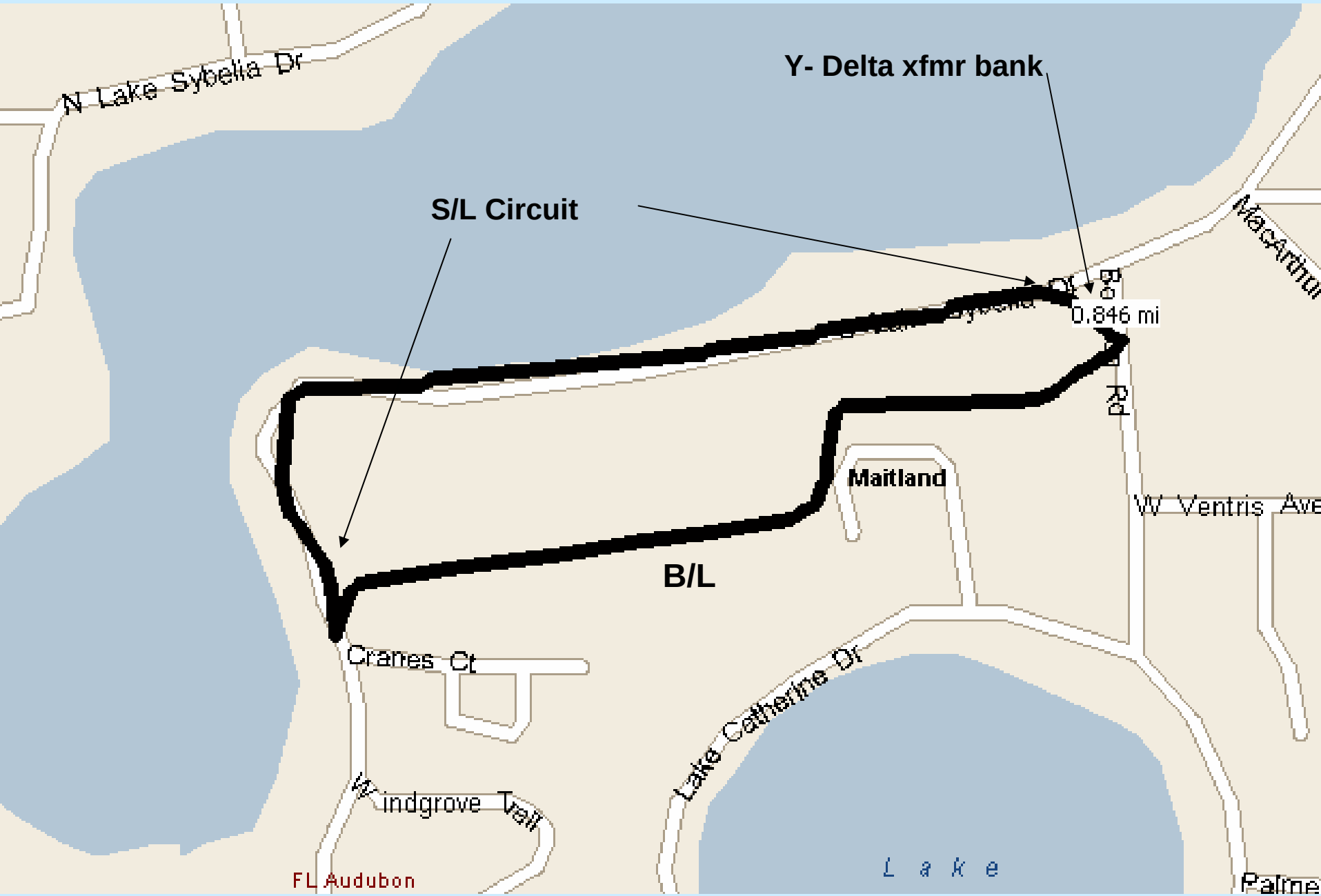
  Rs = 312 ohms

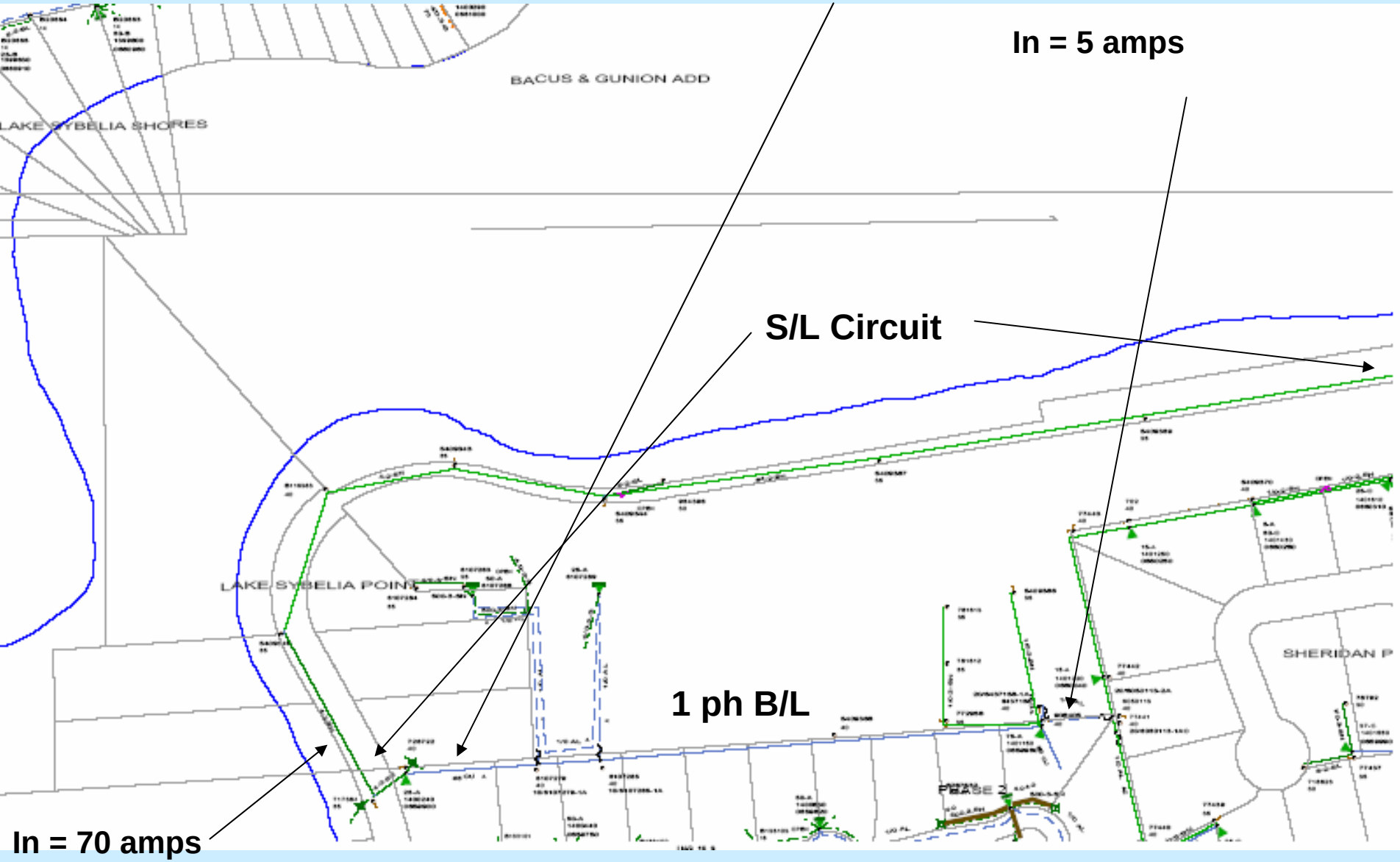
  Isc = 26/312 = 83 ma

  This could be lethal!

Check Neutral currents

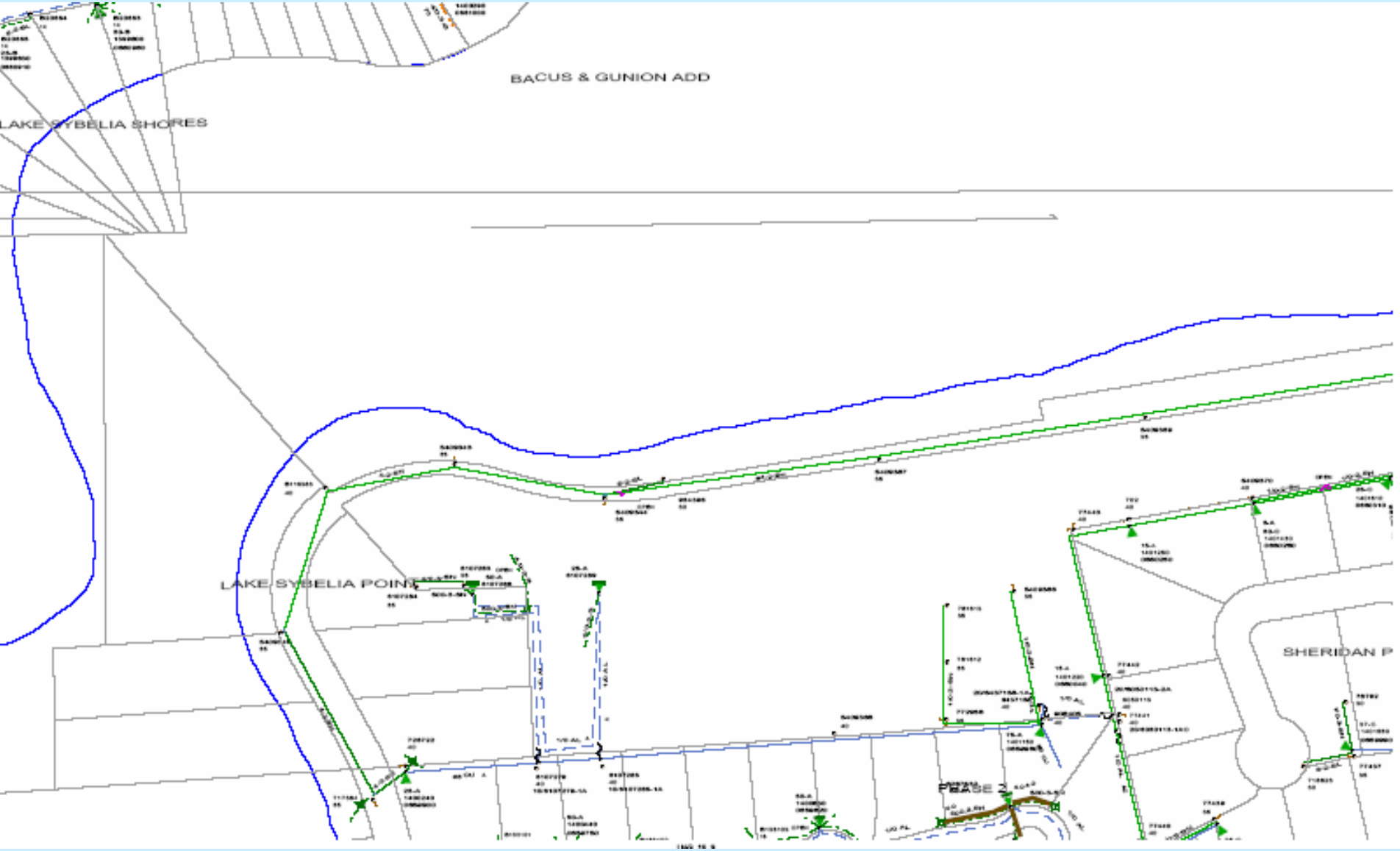
- Branch line neutral current at tap = 5 amps
- Checks along branch line show neutral current increasing as we go out on the branch line!
- Neutral current at dead end = 65 amps!
- Where is the source of the current???


Y- Delta xfmr bank
S/L Circuit
B/L
0.846 mi
N Lake Sybelia Dr
MacArthu
Rd
Maitland
W Ventris Ave
Cranes Ct
Lake Catherine Dr
Windgrove Trail
FL Audubon
L a k e
Palme


In = 55 amps
In = 5 amps
S/L Circuit
1 ph B/L
In = 70 amps
BACUS & GUNION ADD
LAKE SYBELIA SHORES
LAKE SYBELIA POINT
SHERIDAN P
PEASE 2

Mysterious Neutral Current

- Dead end of branch line is xfmr station pole and has a secondary drop across the road to a lift pole at the edge of a lake.
- Lift pole has a secondary riser down the pole to a service pedestal. Pedestal serves a boat dock on the lake.
- AHA! – a wire on the dock must be contacting the lake and leaking current into the soil!


BACUS & GUNION ADD
LAKE SYBELIA SHORES
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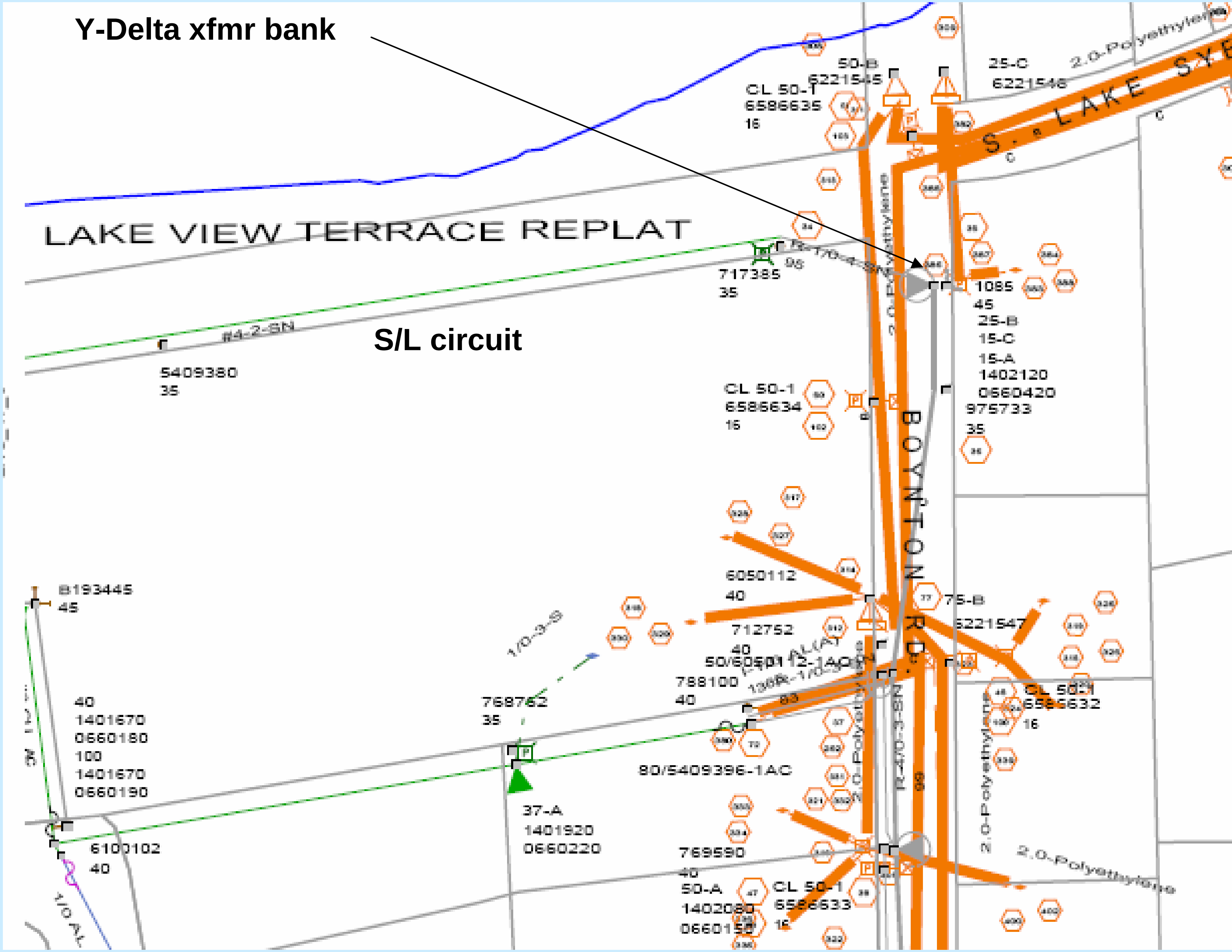
PEASE 2
SHERIDAN P

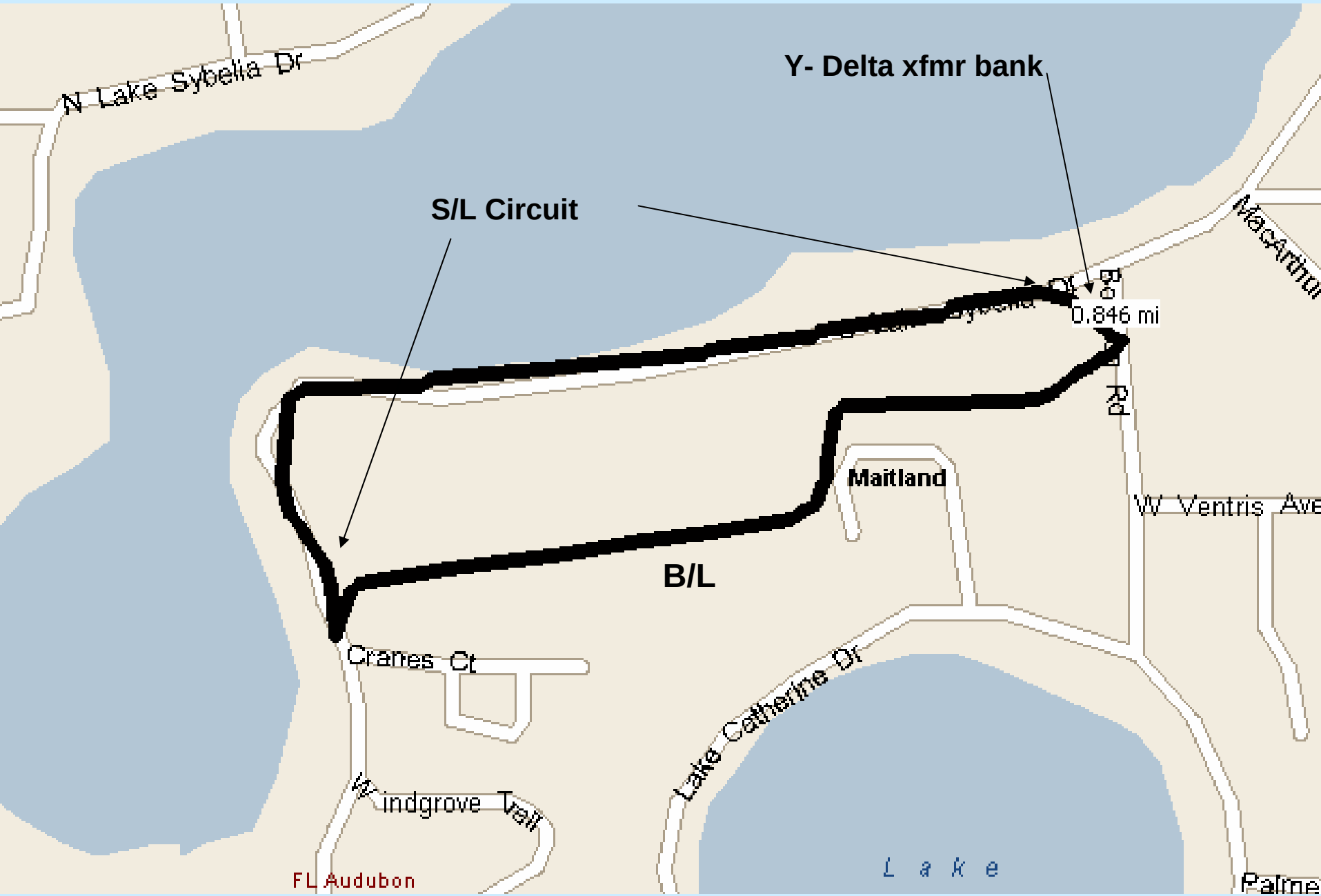
Check pedestal Currents

- None – nothing – zip NADA!
- Where is the current?
- A street light duplex cable circuit goes north along the lakeshore road.
- No street lights are burning
- Neutral of street light circuit measures 70 amps!!!!!!

Mysterious Currents Continue

- Investigate street light circuit
- 4 spans north the SL hot leg circuit is open
- Lights farther out must be served by another source
- Followed SL circuit and it becomes open wire instead of duplex cable
- Source found about 0.5 miles away is a Y-Delta xfmr bank.


Y-Delta xfmr bank
S/L circuit
LAKE VIEW TERRACE REPLAT
S. LAKE
BOYNTON RD.
2.0-Polyethylene
50-B
6221545
25-C
6221546
CL 50-1
6586635
16
717385
35
#4-2-SN
5409380
35
1086
45
25-B
15-C
15-A
1402120
0660420
975733
35
CL 50-1
6586634
16
6050112
40
712752
40
75-B
6221547
788100
40
CL 50-1
6586632
16
8193445
45
40
1401670
0660180
100
1401670
0660190
768762
35
1/0-3-S
80/5409396-1AC
37-A
1401920
0660220
6100102
40
769590
40
50-A
1402080
CL 50-1
6586633
16
1/0 AL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N Lake Sybelia Dr
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Windgrove Trail
FL Audubon
L a k e
Palme

Mysterious Currents Continue!

- Check currents on SL circuit at xfmr
- Hot leg has 70 amps
- Neutral has nothing!
- Following circuit back we find 2 spans of duplex cable in the middle of an open wire circuit
- Upon inspection and tong ammeter checks the transition from open wire to duplex is reversed!

Mysterious Currents Found!

- During recent storm a tree downed SL circuit
- 2 spans of open wire replaced with duplex cable
- Connections at one end of duplex reversed to open wire conductors
- Hot leg bonded to neutral wire!!!!!

Mysterious Currents Found!

- Loop circuit distance was 0.85 miles
- Short circuit calc shows about 100 amps
- Current along branch line going to earth at driven grounds
- Results in decreasing neutral wire current as you get closer to source end of B/L

S/L Circuit Opened

- Vne at customer meter drops from 26 volts to 2 volts
- Source definitely found
- S/L circuit wiring corrected
- Problem Resolved
- CATV drop had burned up when power restored after storm

Was This Really Stray Voltage?

- No Definition in IEEE 100
- Not a temporary fault (wiring error was permanent)
- Not a true neutral to earth voltage from “normal” system operation
- A modified “contact voltage”?

What will the standard cover?

- Touch and Step Voltages due to steady state operation of the distribution system?
- Neutral as well as contact voltages?

Other Issues

- Gas Line Bonding and grounding?
- Substation grid potentials
- Use of Saturable reactors
- Phone & CATV bonding issues
- 2005 NEC Code changes for Swimming Pool Bonding
- Third Harmonics are +/- 50% of Neutral Currents = > Vne

Other Stray Voltage Mitigation

- Reduce Neutral Currents
  - Balance Loads
  - Install 3rd Harmonic Filter out on feeder
- Install “Blocker” reactor between primary and secondary neutral systems
- Must separate CATV and phone grounds from power neutral at service entrance

2005 NEC Code Changes

- Section 680.26
- New Item on Equipotential Bonding
- 12” x 12” Ground Grid required 3 ft out from Non Bonded Pools

References

- NETRAC Study
- EPRI STUDY
- IEEE beginning work on standard for stray voltage
- Next S.V. W.G meeting at P.E.S. in Montreal
- C. Williams Chairman

TROUBLE-SHOOTING EARTH-TO-NEUTRAL VOLTAGE

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Parameters Affecting Neutral-To-Earth Voltage Along Primary Distribution Circuits

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Stray Voltage Standards Website
http://grouper.ieee.org/groups/td/dist/stray/