'07

Consolidated Edison Company of New York and the Electric Power Research Institute

2007 Jodie Lane National Conference
for Stray Voltage Detection, Mitigation, and Prevention

conEdison  EPRI
A REVIEW OF STRAY VOLTAGE IN NYC

Data provided by ConEd
PowerPoint by Roger Lane
My Goal in January 2004 & Now

- Safer Streets in NYC
- Materially reduce the risk to the pedestrian from SV
Motivation to Fix the Problem

- The big picture
  - All systems decay over time
  - If the system does not have an effective and timely way to detect system failures, these defects will accumulate
  - The accumulated system failures will injure pedestrians

- What does this mean to you?
  - On average in Manhattan you pass a SV every half mile. When you walked from the subway in Union Square to Irving Place today you walked passed one SV. The number of undetected SV that you passed was likely higher. The number of system failures higher still.
The Chonology of SV

- The electrical distribution system decays over time
- The decay reaches a point where a conductor is exposed. This is system failure.
- If a contact path is created to the surrounding structures, then SV is created
- **The contact path may come and go, therefore SV may come and go**
- The decay → exposed conductor → “system failure” remains until detected and mitigated. This is the pedestrian risk.
What is Stray Voltage?

- Stray Voltage is voltage detected in a location where it should not be present.
- If the electrical distribution system were working as designed there would be no stray voltage.

- Cause: a failure of the electrical distribution system.
- Effect: Stray Voltage.
- Impact: Pedestrian risk of injury or death
3 Years have Past, What Has Been Done?

- The distribution system of 739,000 locations had been tested 4 times: 1x in 2004, 1x in 2005 and 2x in 2006.
- This means more than 3 million measurements have been taken for SV.
- NYC may be the most tested distribution system in the U.S.
- A unique and more comprehensive mobile SV testing system was created and implemented.
- This mobile system searches for SV from all sources: ConEd, DOT, Customer, NYFD, NYPD, Contractors, CATV.
3 Years have Past, What Has Been Found?

- System failures are more widespread than expected

- 8,223 locations had Stray Voltage
  - On average, 9 SV locations detected every day in 2006

- 704 people were shocked
  - On average, one person shocked every other day in 2006
3 Years have Past, What Has Been learned?

- SV comes and goes...the decay is permanent
- This intermittency leads to SV detection that is not 100% effective at finding all system failures...false negatives are the result of this intermittency
- We know that the system decays but we don’t know at what rate or if the rate is changing
- More frequent testing and more comprehensive test methods are leading to increased numbers of Detected SV
3 Years have Past, What Can We Surmise?

- **IF THERE IS NO COMPREHENSIVE, EFFECTIVE, AND FREQUENT METHOD OF SV DETECTION & MITIGATION THERE WILL CONTINUE TO BE LARGE NUMBERS OF UNDETECTED SYSTEM FAILURES AND LARGE NUMBERS OF UNDETECTED SV IN THE SYSTEM.**

- In all years prior to 2004 this was true. Undetected system failures and undetected SV grew & accumulated since the beginning of the ConEd system.
3 Years have Past, What Can We Surmise?

- During 2004 thru the present a more thorough test process was put in place. However, since these tests were ONLY SEMI ANNUAL and because SV comes and goes we can surmise that not all SV is detected as it occurs and not all system failures have been detected or will be detected.

- Human and animal shock events will continue.

- Pedestrians will still be at risk.
What Can You Do To Materially Improve Pedestrian Safety?

- Redesign and rebuild the system to include:
  - New designs that reduce the rate of decay of the system
  - Continuous detection of SV and automatic mitigation when SV occurs
  - New designs that add passive barriers e.g. non conductive materials

- Develop a detection device and implement in the system or on the 739,000 locations.
  - as a community of utility engineers create a consensus definition of requirements of such a device
  - Encourage / incentivize Universities and Technology businesses to design and develop the device/system

- Use mobile trucks or another comprehensive detection system to achieve at least every other week evaluation of the system
What Can We Do Today To Materially Improve Pedestrian Safety in NYC?

- The only way to find all of the accumulated undetected system failures is to continually test for SV. Whenever the low impedance path is made the SV will be detected.

- In the near term, to achieve a 90% reduction of undetected SV, test the system every other week...Add 40 More mobile trucks
Your contribution to a solution is not unnoticed

- Thank you for the work you are doing
2007 Jodie Lane National Conference for Stray Voltage Detection, Mitigation and Prevention

June 5th 2007

Agenda
Agenda Day One

Five Topics Relevant to the Subject Matter

– Measurement and Detection
– Mitigation
– Case Studies
– Analysis of Data
– Roundtable Discussion

Neutral Corrosion – Cable Replacement
Transmission Testing for Stray Voltage
Development of New Tools
Con Edison Service Territory

Con Edison Company of NY
- NYC and Westchester
- Area: 660 sq. mi. (Elec & Gas)
- Population: 9.1 million

- 3.1 million electric customers
- 13,141 MW 2006 Peak
- In some areas, Load Density greater than 2100 MW per Sq Mile
Mission

“Protect the public and improve public safety through the mitigation and elimination of stray voltage”
Stray Voltage Mitigation Strategy

• Testing
  – Detect, protect, and repair stray voltage before the public

• Inspection
  – Find and repair possible precursors to stray voltage

• Design / Rebuild
  – Implement improved designs to mitigate stray voltage
  – Continually renovate the system

• Research and Development Initiatives
  – Never status quo, innovation

• Awareness
  – Industry and public
Electric Shock Reduction (Jan 1 - Apr 30)

Total Electric Shocks Reported

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Electric Shocks</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>148</td>
<td>28%</td>
</tr>
<tr>
<td>2005</td>
<td>107</td>
<td>33%</td>
</tr>
<tr>
<td>2006</td>
<td>72</td>
<td>24%</td>
</tr>
<tr>
<td>2007</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>
Electric Shock Reduction (Jan 1 - Apr 30)

Electric Shocks Reported (conEd)

- 2004: 128 shocks (45% decrease)
- 2005: 71 shocks (41% decrease)
- 2006: 42 shocks (52% decrease)
- 2007: 20 shocks

Number of Electric Shocks
Manual Testing
Stray Voltage Testing

To test all company facilities and streetlights for stray voltage

- 274,000 underground structures
- 285,000 overhead poles
- 177,000 streetlights
Mobile Stray Voltage Program
Mobile Detector Program

• Detector certified to detect 6V at 25ft, 20mph
• 4 system wide scans planned for 2007

• Major improvements over manual testing
  – Sensitivity
  – Speed
  – Flexibility
  – Test entire environment
  – Proactive
Additional Public Safety Benefit

- Extend testing to whole environment has significant impact on safety

- Only 275 (6% of all detected) on Company owned assets

<table>
<thead>
<tr>
<th>SVD Stray Voltage Not Tested in Manual Programs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidewalk</td>
<td>330</td>
</tr>
<tr>
<td>Gate</td>
<td>111</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>76</td>
</tr>
<tr>
<td>Cust Eqp</td>
<td>61</td>
</tr>
<tr>
<td>Bus Shelter</td>
<td>39</td>
</tr>
<tr>
<td>Phone Booth</td>
<td>23</td>
</tr>
<tr>
<td>Non-CE Cover</td>
<td>20</td>
</tr>
<tr>
<td>Fire Hydrant</td>
<td>18</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
</tr>
<tr>
<td>Water Pipe</td>
<td>2</td>
</tr>
<tr>
<td>Trench</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>684</td>
</tr>
</tbody>
</table>
Structure Inspection Program
Structure Inspection Program

• **Scope of Program**
  To conduct inspections of all underground and overhead facilities, perform repairs and identify rebuild areas

• **Inspection Progress**
  - 533,000 inspections completed
Rebuild Program
Rebuild Program

• **Scope of Program**
  Identify area of repairs, issue layouts and prioritize Construction work

  – 70,000 miles secondary cable on system
  – Replace 2,000 miles of cable per year
  – 30-40 year replacement cycle
  – 8,000 miles installed
Engineering / Design Programs
Streetlight Isolation Transformers
Streetlight Painting Program

- New York City DOT program
- Insulating paint rated to protect up to 20V
- DOT has completed 80% of 177K streetlights & traffic lights to date
Streetlight Safetap

• Streetlight Safetap®
  – Provides a quick, convenient source of 120 volt temporary power from streetlights using existing fuse holders
Research and Development
Monitoring of Service Boxes & Manholes

- Power Line Carrier
- 13 sensors and 1 collector installed 2006
- Local communication verified
- Establishing communication to the end user
Network Transformer Vault Monitoring

- Sensor developed and installed at a network transformer vault for testing
Real Time Monitoring: Streetlight Photo Cell

Project started January 2007
  • 25 Photo Cells, 1 Node installed
  • Wireless lamp status reporting at 4 hr interval
  • Investigating potential incorporation of stray voltage sensing capability
Composite Covers
Vented Composite SB Cover

- Non Conductive
- Pilot Program to install 1000 covers Fall 2007
- Blast tests
- ADA Compliant
- Field Demonstrations
  - Weight – 125 lbs
  - Non corrosive
  - Slip resistant
Stray Voltage Performance
Stray Voltage Conditions Found vs Number of Tests Performed

![Bar graph showing the number of stray voltage conditions found and tests performed from 2004 to 2007.](image-url)

- **2004**: 2,384 conditions, 2,000 tests
- **2005**: 2,508 conditions, 2,500 tests
- **2006**: 3,331 conditions, 3,189 tests
- **2007**: 831,000 conditions, 1,000,000 tests (as of 4/30/07)

The graph illustrates the trend of increased conditions and tests performed over the years.
Stray Voltage Locations

ESR Locations
2004 to 4/30/07

- 25%
- 13%
- 17%
- 44%

ENE Locations
2004 to 4/30/07

- 85%
- 5%
- 3%
- 6%
- 1%

*Non-conEd structures include Cust. Equipt., Awnings, Fences, Hydrants and Scaffold

conEd Structures
Sidewalks
Non-conEd Structures*
Overhead Infrastructure
Streetlights
Root Cause Ownership for SV Detected/Reported

SV Detected 2004 to 2007 YTD

- All Others: 55%
- Con Ed: 45%

SV Detected in 2007 Only

- All Others: 65%
- Con Ed: 35%
Awareness
Awareness 2007

• Jodie Lane Conference (NYC)
• Electrical Network Systems Conference (Columbia, SC)
• EUCI - Neutral Grounding SV Seminar (San Diego, CA)
• IEEE – Conference (Orlando, FL)
  – Working group webcasts (two this year)
• Utility Safety Conference (Seattle, WA)
• Western Energy Institute Conference (Phoenix, AZ)
Awareness

- City agency training and awareness
  - DOT, NYPD, FDNY/EMT
- Presentations to public officials & Community Boards
- NYC Department of Buildings
Customer Awareness

• Customer reported shock from stove in Westchester
• Customer reported shock from faucet in Brooklyn
• Customer reported shock on front porch in Brooklyn
• Customer reported shock while washing deck in Staten Island
• Person reported shock on fifth floor of office building in Manhattan
• Person shocked from circuit panel in basement in Brooklyn
Questions?
Underground Electrical Safety Program

NSTAR Distribution Technical Engineering

Christopher P. O’Neil P.E.

June 5 & 6, 2007
81 communities
1.1 million electric customers
5,000 MW demand
Overview - Overhead Distribution System

- **4kV**: 331 circuits, 1,943 circuit miles, serving 208,000 customers (approx. 20% of total NSTAR customers)

- **15kV**: 324 circuits, serving 418,000 customers (approximately 40% of total NSTAR customer base)

- **25kV**: 210 circuits, serving 220,000 customers (approx. 21% of total NSTAR customers)
Overview - Underground Distribution System

Approximately 39,000 Manholes

• **4kV**: 276 circuits, 900 circuit miles, serving 110,000 customers

• **15kV** (excluding DSS): 128 circuits, serving 47,000 customers (approximately 4.4% of total NSTAR customer base)

• **15kV Distribution System Supply (DSS) Lines**: 375 lines

• **Network**: 150 network feeders and 1,500 transformers

• **URD**: Over 2,660 miles of 15 & 25kV cable
  – Over 800 miles of direct buried HMWPE non-jacketed cable
UNDERGROUND ELECTRICAL SAFETY PROGRAM

The Underground Electrical Safety Program is an incremental effort undertaken by NSTAR over and above its existing work plans to improve service and reliability levels for our customers.

The Program is designed to meet three objectives:

1. to assess the condition of infrastructure in use on the NSTAR Electric system;

2. to identify infrastructure that needs repair, replacement or remediation; and

3. to complete high priority repairs, replacements and remediation of that equipment on a timely basis.
The 2006 work plan:

- Manhole inspections (approximately 5,500) and completion of inspection-related repairs, replacements and remediation.

- Stray voltage-indication testing (approximately 40,000) and any subsequent repairs and remediation of NSTAR-owned secondary risers, secondary pedestals and padmount transformers in any location served by the underground distribution system and accessible to the public;

- Visiting sites identified in 2,831 demolition permits within the City of Boston to validate that service cutoffs are complete;

- Evaluation, assessment and potential deployment of new technology and equipment;

- Development of information systems to track inspections and compile results; and

- Forensic analysis of failed equipment.
Prioritization:

• Facilities within the City of Boston and City of Cambridge for investigation through the Underground Electrical Safety Program. These systems were tested in their entirety in year one because these systems represent the majority of NSTAR Electric’s underground infrastructure.

• During the second quarter, NSTAR finalized and implemented a new manhole inspection form. This scannable form will aid in tracking all inspections and subsequent repairs entered into the company’s manhole database.

• NSTAR developed deficiency criteria to define high-priority follow-up work. This two-tier criteria approach is based on an analysis of inspections performed in the first quarter, which identified manholes with equipment and design considerations, along with cable and joint support deficiencies.
### Underground Electrical Safety Program - Manholes

<table>
<thead>
<tr>
<th>Period</th>
<th>Network Manholes Inspected</th>
<th>Other Manholes Inspected</th>
<th>Total Manhole Inspections</th>
<th>Demolition Cutoffs Verified</th>
<th>Priority Manhole Repairs Completed</th>
<th>YTD Priority Manhole Repairs To Be Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Qtr</td>
<td>307</td>
<td>1,466</td>
<td>1,773</td>
<td>610</td>
<td>350</td>
<td>-</td>
</tr>
<tr>
<td>2nd Qtr</td>
<td>208</td>
<td>1,128</td>
<td>1,336</td>
<td>611</td>
<td>155</td>
<td>-</td>
</tr>
<tr>
<td>3rd Qtr</td>
<td>235</td>
<td>1,012</td>
<td>1,247</td>
<td>811</td>
<td>133</td>
<td>-</td>
</tr>
<tr>
<td>4th Qtr</td>
<td>474</td>
<td>862</td>
<td>1,336</td>
<td>485</td>
<td>68</td>
<td>572</td>
</tr>
<tr>
<td>Total</td>
<td>1,224</td>
<td>4,468</td>
<td>5,692</td>
<td>2,517</td>
<td>706</td>
<td>572 (n.2)</td>
</tr>
</tbody>
</table>

| Target For 2006 | 1,200 | 4,300 | 5,500 | 2,831 (n.1) |

(n.1) NSTAR Electric initially projected that it would complete 4,000 cutoff verifications associated with demolished buildings. Of this amount, 2,831 were sites identified through an exchange of records with the City of Boston and the Company targeted these sites on a priority basis in 2006.

(n.2) NSTAR Electric projected the number of priority manhole repairs to complete would rise as more inspections are performed.
Highlights 2006 Manhole Program:

• NSTAR performed 1,224 network manhole inspections over the year. These were targeted inspections to verify records, condition of secondary mains, and secondary limiters placement and condition.

• As a result of planned work during the year an additional 4,468 manholes were inspected.

• Overall, NSTAR completed 5,692 manhole inspections. During this same period, remediation activities focused on high-priority repairs identified. 706 of these maintenance upgrades were completed at year end.

• In addition to these inspections, the Company checked on the cut-off status of 2,517 demolition locations during the course of the year.
Verification of Demolition Cut-Offs

- As part of the inspection process, the Company identified the location of suspected service cutoffs relating to building demolitions. Of the 2517 locations checked, the Company was able to verify the cutoff status of all locations.

- Of the 2,517 locations, 1,450 service cables were verified cut in the manhole and 1,029 services were verified connected to an active service account. These locations did not require further action.

- 38 service cables was discovered not connected to a facility and subsequently de-energized.
# Underground Electrical Safety Program – Stray Voltage

<table>
<thead>
<tr>
<th>Period</th>
<th>NSTAR Locations Tested (includes padmounts &amp; risers)</th>
<th>Positive Detections</th>
<th>Owner of Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Patrols</td>
<td>Sarnoff</td>
</tr>
<tr>
<td>1st Qtr</td>
<td>11,166</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>2nd Qtr</td>
<td>8,148</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>3rd Qtr</td>
<td>18,031</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>4th Qtr</td>
<td>15,853</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>53,198</td>
<td>5</td>
<td>63</td>
</tr>
</tbody>
</table>

Target For 2006: 47,500
Highlights 2006 Stray Voltage testing:

- NSTAR performed **53,198** stray voltage tests.

- The Sarnoff test vehicle was used on a five-day, off-shift schedule, with a focus on the downtown Boston and surrounding areas. Testing was completed on all required facilities.

- The Sarnoff vehicle was responsible for 89% of all positive stray-voltage detections in 2006. NSTAR Electric verified that **2,517** demolished locations have been cut off, or have an existing active service.
Stray-Voltage Testing

• A complete sweep of the city of Boston and the city of Cambridge have been tested for stray voltage.

• The Company detected, and subsequent repairs have been made at 71 locations which tested positive for the presence of stray voltage. 10 of the 71 positive locations were NSTAR owned equipment.

• NSTAR Electric follows a “Find It, Fix It” principle with coordination of the owner of issue in circumstances where the affected equipment was not NSTAR Electric-owned.
Questions?

Scheduled Break
Nuisance Shocking

NSTAR Distribution Technical Engineering

Christopher P. O’Neil P.E.

June 5 & 6, 2007
Elevated Neutral to Earth Voltage vs. Inadvertent Contact voltage

• The subject of “Stray Voltage” has long been an area of concern and subjective interpretation for utilities, regulators and the public. Issues range from induction of voltage onto metallic infrastructure such as conduits, shield wires, water lines, and gas lines to unanticipated current paths created by grounding configurations and connection impedances.

• Recent events have confused the usage of this term so that the general public now associates it with dangerous voltages which might result in injury. The historical usage of the term “stray voltage” is associated with a non hazardous elevated neutral voltage.
What is Elevated Neutral to Earth Voltage?

- Normal Load, and fault currents flowing through the impedances of the neutral or grounding conductors to earth, produce neutral to earth voltage (NEV). There are multiple paths from the neutral or grounding system to earth such as ground rods, metallic water lines, or other ground electrodes. This means that there is always voltage to earth. Any metallic structure connected to the neutral or the grounding system will also be at the same NEV.
What is Inadvertant Contact Voltage?

• Contact voltage occurs when an energized electric line inadvertently comes in full or partial contact with earth or a metallic object. The contact can be due to a breakdown of the electric insulation, from an improper connection, damage from a vehicle accident, vandalism, or a cable being dug up accidentally.
ELECTRIC DELIVERY
SERVICE AREA

81 communities
1.1 million electric customers
5,000 MW demand
Stray Voltage on the Cape -
Summary

• Complaints are received annually from customers receiving shocks on outside showers/water faucets in the Cape District. These calls are not localized.

• As with typical rural distribution systems the problem arises particularly due to the following:
  – Distribution system, with predominant single phase loading, difficult to balance.
  – Redundant paths to hardwired multipoint grounded system neutral do not exist throughout the Cape as they do in urban areas.
    • Municipal water systems, Gas, Communication
  – Distribution Supply circuits that share a transmission corridor
  – High soil resistivity,
  – Intermittent equipment locations resulting ,sparse grounding, of system neutral,
  – Increased commercial & residential harmonic loading
  – People barefoot in wet conditions and the above are the ideal parameters to generate ENV (elevated neutral voltage) and Metallic Object to Earth Voltage (MOEV) at or near the level of perception
What level of stray voltage is a concern?

- The Massachusetts Department of Telecommunication and Energy {now DPU} has ordered immediate repair if there is a voltage reading of 20 volts or greater. If the voltage reading is between 8 and 20 volts, repairs must be made within 24 hours. Mitigation of voltage readings below 8 volts is left to the discretion of the Utility.

- It is recommended that actions be taken to reduce neutral to earth voltage when the NEV at the service entrance or between contact points is higher than the 2 to 4 volts range level. Unfortunately, there is no standard for stray voltage and this is only a recommend guideline from the U.S. Department of Agriculture.

- A standardized measurement of stray voltage is defined as "the voltage measured across a 500 ohm (nominal) resistance connected between two animal contact points."
Where does Elevated NEV come from?

- Utility Sources of stray voltage include, but are not limited to; electrical shorts (Transient faults) in equipment, defective underground cable, unbalanced loads that result in a voltage drop on neutral conductor, corroded neutrals, corroded bonding connections, and missing or inadequate grounding systems.

- A common private property source of stray voltage is the result of interconnection of equipment grounding conductors with the neutral conductors. The grounding conductor is used to ground metal equipment and should never be one of the conductors used to supply power. The neutral, or other conductor supplying power, should never be connected to the metal case of equipment nor should it be interconnected with the grounding conductor at any point other than the main electric service panel.
Multi-Grounded Neutral (MGN) – Multiple return paths
Separating the neutral from the equipment grounds

Normal current on Equip Gnd = 0
Separating the neutral from the equipment grounds

Normal neutral current takes shared path
First Call Response - Cover the Basics

• Determine the source. Transient fault or normal neutral current. On property or off property

• Inspect the continuity and resistance of the circuit neutral path back to the source transformer. Replace defective or questionable connections and fill in any sections of discontinuities.

• Survey/reinforce distribution system neutral on circuits. Ensure continuity toward source and drive multiple deep earth grounds min 8x per mile equipment.

• Ensure multiple redundant neutral return paths through intersystem bonding with communication messengers as now required NESC rule 97G.
NEW NESC Requirement 2007
interconnect telecom/Cat messenger with ground

Similar common bonding on both sides of the service point.

GROUNDING OF OVERHEAD TRANSFORMERS ON GROUNDED WYE CIRCUITS
(Except 3 phase delta secondary services)

NESC reference Rule 570. Bonding of communication systems to electric supply systems where both electric supply systems and communication systems are grounded on a joint use structure, either a single grounding conductor shall be used for both systems or the electric supply and communication grounding conductors shall be bonded together, except where separation is required by Rule 57A. Where the electric supply utility is maintaining isolation between primary and secondary neutrals, the communication system ground shall be connected only to the primary grounding conductor.

GROUNDING OF OVERHEAD TRANSFORMERS ON UNGROUNDED WYE AND DELTA CIRCUITS

* A neutral can be extended to an adjacent pole and a down ground connected there, to satisfy the 20F1 requirement.
Multipoint Grounded Neutral

- Multi point grounded electric systems use the ground (or earth) as a common medium to supplement the return of current to the local electric substation or generating plant. Neutral-earth currents typically exist wherever electric power distribution exists. The National Electric Code and National Electric Safety Code define proper techniques for grounding on a utility’s electric system and at residential and commercial structures and buildings. Electric utilities, such as NSTAR, adhere strictly to all NESC codes, in the design and construction of their electric systems.

- Minimizes Hazardous Voltages to Ground

- Provides Low Impedance Path for Ground Faults

- Provides better Grounding for Lightning Protection

- This added safeguard over three phase three wire is more costly by the installation of the 4th neutral wire and multiple down ground connections
Current on the Neutral path

• Currents returning on grounded-wye power systems cause a voltage drop across the impedance of the neutral conductor. Because the neutral conductor is grounded, the impedance of the earth return path in parallel with the impedance of the neutral return path dictates the percentage of earth current and the corresponding NEV at that neutral-grounding point. Current will follow on all return paths in proportion to the conducting path impedances.

• Reducing the impedance of the neutral effectively reduces the amount of current flowing through the earth path and lowers corresponding NEV at that neutral-to-ground bonding point.
  – Increase neutral capacity = reduce voltage drop = reduce potential difference between earthing connection.

• Multipoint low impedance driven grounds ensure effective overcurrent protection during transient single line to ground SLTG faults

• Multiple redundant hardwired return paths are required to supplement earth return and increase neutral capacity.
Load balancing

- On three-phase, grounded-wye distribution systems with equally balanced 60-Hz phase currents, the net neutral current should be zero. That is, the neutral current from the three phases effectively cancels out. Unfortunately, in the real world, perfect balancing can be upset by many factors such as phase shift, load unbalance and harmonic currents. These phenomena can cause current to flow in the neutral conductor and into the ground rod at each of the neutral-to-ground bonding points, which creates a proportional NEV. Balancing the phase currents can reduce the 60-Hz component of NEV across the entire distribution system.
Harmonic filters
Limit @ service point to IEEE 519

- A recent area of research into NEV concern relates to 3rd harmonic currents flowing on distribution system neutral conductors. This and other odd multiples of the fundamental 60-Hz current add instead of canceling out on the neutral conductor, thereby creating harmonic NEV levels. The causes of these harmonic currents include harmonic generating equipment owned by the end user and circuit resonances created by distributed capacitor banks. Harmonics due to customer loads is expected to increase over time as more equipment such as variable frequency drive washers and air conditioning equipment proliferate and as more televisions, PCs and other home entertainment equipment use increases.

- IEEE 519 WORKING GROUP
IEEE Standard Practices and Requirements for Harmonic Control in Electrical Power Systems
Adequate Service and Equipment Grounding

• Provide adequate electric service and equipment grounding. Customer to ensure effective equipment grounding path to all metal equipment likely to become energized. Separate from neutral beyond the service point main. Provide low resistance equipment ground fault clearing path.

• An effective ground-fault current path must be capable of safely carrying the maximum fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source neutral. Effective ground path = trips overcurrent

• Uniform ground potential rise and better grounding provides effective ground path. Proper installation of an equipotential plane, a grounding grid in the floor that's connected to all metallic equipment.
Equipotential Plane; NEC Agricultural Buildings, Swimming Pools, Fountains & Similar

• Similar to the ground-reference structures used for computer rooms and the ground mats that minimize step potentials at utility substations, the equipotential plane is a useful means of minimizing the effects of stray voltage.

• An equipotential plane typically consists of a conductive wire mesh installed under the area where nuisance shocking has been reported, and bonding conductive materials in the area directly to the mesh. The technique does not reduce NEV levels, but rather provides a uniform voltage gradient in areas where people and animals are likely to insert themselves into the conducting path.

• Bring the outdoor shower into compliance with current NEC requirements and help mitigate the problem as well (NEC requirement Article 547 agriculture locations and 680 Pools & Aquatic environments such as outdoor showers).
Summary ENV Specific Challenges

• It is desirable to keep NEV below the level of perception where practical. Two to four volts of NEV should be reduced where practical. Urgency to reduce the voltage increases rapidly with higher voltages.

• Intrinsically safe voltage levels at that of perception less than 1V are and will continue to be a public concern.

• Rural areas, limited redundant paths, phase balancing and hardwired neutral capacity generalized contributor of high NEV.
Wrap - Up

• NSTAR Electric is Committed to Delivering Great Service, and Safe & Reliable Energy

• We must strive to provide accurate information on our efforts to minimize the effect elevated neutral voltages and high soil resistivity in areas.

• Employees, Customers and the Press need to be reassured that the safety of our customers and our system is foremost.
Stray Voltage at a Remotely Operated Gas Valve

Benjamin Brown – Orange & Rockland
brownbe@oru.com
June 5, 2007
Overview

Orange and Rockland’s Territory & Electric System

Case Background

Investigation and Mitigation Efforts

Solution & Results

Lessons Learned
Orange and Rockland’s Territory and Electric System

Territory:
- Rockland, Orange and Sullivan Counties, New York
- Parts of Northern New Jersey
- Pike County, Pennsylvania
- Approximately 1,300 square miles, serving 294,000 customers

Transmission system:
- Operating voltages of 345kV, 138kV, 69kV and 34kV
- Nearly 300 miles and 3,500 acres of right-of-way

Distribution system:
- Open-looped overhead radial system interspersed with underground residential distribution (URD)
- Operating voltages of 34.5kV, 13.2kV and 4kV
- Approximately 4,300 circuit miles of overhead and underground cable
Background

Gas Crews raised a safety concern:

- Getting shocked while working at the Remotely Operated Valve (ROV)
- Noticed arcing between the two inch stanchion and one inch tap pipes on either side
- Recorded between 9.4VAC and 21.4VAC at the ROV depending on the reference point used

Remotely Operated Valve location:

- Approximately 300 feet from a 138/13.2 kV distribution substation
- Directly beneath two 138kV transmission lines
Remotely Operated Valve (ROV)
Investigation

Gas rectifier:
- Checked equipment and found there was an AC component to the DC output

Electric transmission and distribution system:
- Installed additional grounds at all distribution poles in the area
- Installed strain rod and reinsulated the pole servicing rectifier
- Concluded that terrain environment contributed to natural or baseline voltage of 3.5VAC
- Determined that the system neutral voltage was impressed on the secondary neutral
Solution

Electric distribution system modifications:
- Installed a neutral isolator at the transformer pole servicing the rectifier
- Separated the system and secondary neutrals at the pole adjacent to rectifier

Gas rectifier:
- Installed capacitor filter on rectifier

Gas operating procedural changes:
- Temporarily bond the various stanchions at the ROV prior to performing work
- Disable rectifier while working at the ROV
Neutral Isolator – Ronk Blocker®

- Separates system and secondary neutrals
- Bridges the neutrals in the event of a fault that exceeds the device’s rating
- Transformer ground must be disconnected from the secondary ground/bushing

Transformer

Secondary Neutral

Primary Neutral

6’ (MIN)
Results

- Mitigated voltage readings to baseline
- Reacquired confidence of gas personnel to safely work on ROV
- Improved pedestrian safety from possible stray voltage along electric distribution system
Lessons Learned

- Standard and proven investigation techniques successfully used
- Close cooperation between electric and gas necessary when co-locating critical facilities on common property
Thank you

Benjamin Brown – Orange & Rockland
brownbe@oru.com
Case Study

Graciela Varela
Distribution Engineering
Con Edison
• Extend testing to whole environment has significant impact on safety

(Totals for 06/07 Rate Year, plus April 2007)

<table>
<thead>
<tr>
<th>SVD Stray Voltage Not Tested in Manual Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidewalk</td>
</tr>
<tr>
<td>Gate</td>
</tr>
<tr>
<td>Scaffolding</td>
</tr>
<tr>
<td>Cust Eqp</td>
</tr>
<tr>
<td>Bus Shelter</td>
</tr>
<tr>
<td>Phone Booth</td>
</tr>
<tr>
<td>Non-CE Cover</td>
</tr>
<tr>
<td>Fire Hydrant</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Water Pipe</td>
</tr>
<tr>
<td>Trench</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
Case Study: St. Catherine’s Church

Feb 28, 2007

112V on fence

Service duct cracked by tree roots under sidewalk

Detected by mobile detector and repaired
Questions?
Detection and Mitigation of Stray Voltage in Underground Distribution Systems

Aaron Prazan
ConEdison
prazana@coned.com

David Kalokitis
Power Survey Company
dkalokitis@powersurveyco.com

June 5th 2007
Introduction

• Aaron Prazan, Engineer
  ConEdison Distribution Engineering – focused on analysis of testing and inspection programs as part of a stray voltage mitigation strategy

• David Kalokitis, CTO
  Power Survey Company – a technology and service provider focused on detection and mitigation of Stray Voltage
Presentation Overview

- Stray Voltage Concerns
- Challenges
- Mitigation Strategy
- SV Emergence Modeling
- Mitigation Program Findings
- Mobile SV Detection Equipment & Methods
- Troubleshooting Approach
- Conclusions
Mission Statement

“Protect the public and improve public safety through the mitigation and elimination of stray voltage”
Stray Voltage Concerns

• Safety Concerns
  – Hazard to general public (human and animal)

• Regulatory Compliance
  – Increasing trend to mandate testing

• Operational Efficiency
  – Manual testing is time consuming, labor intensive, limited to specific test object
  – Testing activity should be performed in a continuous manner
  – Test methods should uncover traditional and non-traditional hazards
Strategy: Test, Inspect, Upgrade

• Reduce exposure now
  – Multiple system tests
  – Corporate culture change/awareness

• Reduce emergence in future
  – Inspect & Repair
  – Capital improvement
  – R&D
Reduced Stray Voltage Exposure Thru Multiple Scans

- Assumptions
  - New SV created over time
  - Repeated testing to reduce exposure

- Expected result
  - Fewer SV found with each scan
  - Fewer SV on system at all times
  - Major reduction in shocks
Reduced Stray Voltage Exposure Thru Multiple Scans (cont’d)

Finding less SV during successive scans

- Catching up with emergence rate
- Real measure of success is reduced shocks
SV Emergence Rate

Data gathered from special test areas allows estimate of ‘emergence’ of new SV on the system.

- 3200 ENE predicted per year, system-wide

Actual findings have been consistent with these projections

~2900 detected >4.5V to date

~3000 projected by completion of survey #3 in summer 2007
Reduction in Severity

Observed voltage levels reduced over time

<table>
<thead>
<tr>
<th>Year</th>
<th>Detected SV Voltage</th>
<th>Shock Report Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>32</td>
<td>42</td>
</tr>
<tr>
<td>2005</td>
<td>23</td>
<td>42</td>
</tr>
<tr>
<td>2006</td>
<td>23</td>
<td>48</td>
</tr>
<tr>
<td>2007 (to date)</td>
<td>19</td>
<td>22</td>
</tr>
</tbody>
</table>
Results of 2006 Mobile Testing Program

- 4085 total SV detected in 1 year
  - 260 covers
  - 3222 streetlights/traffic lights
- Over 18,000 miles covered
- Mobile testing goes where other testing programs do not reach

<table>
<thead>
<tr>
<th>Stray Voltage Sources Not Testable in Manual Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidewalk</td>
</tr>
<tr>
<td>Gate</td>
</tr>
<tr>
<td>Scaffolding</td>
</tr>
<tr>
<td>Customer Equip</td>
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<tr>
<td>Bus Shelter</td>
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</tr>
<tr>
<td>Non-CE Cover</td>
</tr>
<tr>
<td>Fire Hydrant</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Water Pipe</td>
</tr>
<tr>
<td>Trench</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>
### Stray Voltage Not Confined to Manholes Only

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33V</td>
<td>Brooklyn mailbox</td>
<td>caused by burned service leg underground.</td>
</tr>
<tr>
<td>108V</td>
<td>Streetlight on beach</td>
<td>Repaired corroded neutral.</td>
</tr>
<tr>
<td>60V</td>
<td>Foster Av sidewalk &amp; front lawn</td>
<td>Service replaced.</td>
</tr>
</tbody>
</table>

Only 6% of SV found on structure covers.

Asset testing and monitoring doesn’t detect the hazard.
Root Causes

Streetlights
- Duct corrosion or collapse
- Neutral corrosion
- Light damage/removal
- Connections accessible to the public

Structures & Sidewalks
- Chemical damage from salt
- Duct edge/rack arm dig in
- Grounding problems
- Flooding and pump failure
Mobile Detection Approach

• Energized structures and surfaces are sources of Electric Field (E-field)
• A sensitive E-Field detector can move systematically through a territory
• When the E-field detector alarms, a technician pinpoints the source of E-field
• The technician carefully investigates the source and measures voltage
• Document survey coverage and findings
Operation: Live Display
Operation and Features

- Targeted at underground distribution area
- Secondary overhead distribution and temporary shunts do not preclude effective detection with the SVD2000
- Operates at speeds up to 20 MPH
- Sophisticated signal processing allows only 60Hz
- Enabling technology for detection operations
Traditional Manual Testing

• Typically, a worker will
  — Screen assets
  — Use a contact measurement method

• The worker will “find” energized structures
  Only IF
  — The structure is on the asset list
  — Good contact is made to structure
Mobile Stand Off Detection

- Alarm from SVD2000 points to a source of E-field
- Technician will pinpoint source
- The technician carefully investigates the source, knowing it is likely energized
- Use troubleshooting techniques instead of screening techniques
Troubleshooting Methods

• Strong E-field emanating from street lamp
• It’s likely energized, let’s measure the potential
• Use a voltmeter, make contact to the pole and find a good ground
• Be sure the selected ground is at low potential, check for E-field
• Measure with and without 500 Ω shunt (load resistor)
It works because:

• Technician knows there is a source of potential and he will:
  – Pinpoint the source
  – Find and qualify a ground reference point
  – Measure carefully with voltmeter

• Source can be any object or surface
  – No asset list dependence
  – Non-traditional hazards are discovered

• Fast and Efficient
  – Faster cycle time suitable for multiple scans per year
Conclusion

• Detection methods allow rapid discovery of energized structures
• There are many energized structures in our environment
• Repeated scanning and mitigation efforts drive down shock reports
A solution to avoid accidents involving manhole covers

John Alderson and John Newton
Structural Science Composites Company

johnA@structuralscience.net
June 5th 2007
Presentation Overview

- What is a composite?
- History of composite access covering
- Composite technology applied to conEdison’s problem
Composite access covers

- A composite is two or more components brought together to provide ‘better’ properties
- A Resin and Fiber structure
- Manufactured to aircraft quality standard
Upgraded Properties

- Stronger than steel
- Far lighter than steel
- Electrically non-conductive
- Totally non-corrosive
- Very robust
- Sealable
- Low wear characteristics
- Excellent slip resistance
History of Composites

- Aerospace
- Bridge building
- Gas stations
conEdison’s requirements

- Panels that prevent people being electrocuted
- Retro-fit
- Help prevent explosions
- Meet AASHTO regulations
conEdison ‘S’ type panel
Additional benefits for conEdison

- Injury free removal
- Permanent anti-slip
- Hardwearing
- Long life
Composite ‘S’ panels next to traditional ones
What conEdison will be achieving

- A safer environment
- Electrically-non conductive service box covers
- Reduced risk of explosion
- Anti slip surface
- Improved worker H & S
John Newton
CEng. MIEE. AMIMechE. MCM

With a proposed 32” round cover
[wt 75lbs]
conEdison ‘S’ type panel
Technological Solutions to Stray Voltage Mitigation on Electric Distribution System Equipment

Al Homyk
and Don Lucia

Con Edison Company of New York

June 5, 2007
Outline

• Background
• Streetlight Isolation Transformers
• SafeTap
• PhaseSaver Toroidal Autotransformer
• MainsTap
• Questions
Con Edison Service Territory

Con Edison Company of NY
- NYC and Westchester
- Area: 660 sq. mi. (Elec & Gas)
- Population: 8,870,660

- 3.1 million electric customers
- 12,825 MW
  Est. 2004 Peak
- In some areas, Load Density greater than 2100 MW per Sq Mile
Daily Challenges

• Improve public and worker safety
• Develop and implement engineering and operational improvements to reduce energized structures and shocks
Daily Obstacles
Incinerated Streetlight
Mobile Field Office
Power Your Way® Program
DIY (Do It Yourself) Streetlight Relocation Program
Illegal Connectors
X’s, Y’s, Straights, and Neutral Taps
## Streetlight Manual Testing Program

Con Edison Streetlight Stray Voltage Testing Program

### 2006

<table>
<thead>
<tr>
<th>Region</th>
<th>Total Tested</th>
<th>Stray Voltage Found</th>
<th>Detection Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brooklyn</td>
<td>53,651</td>
<td>350</td>
<td>0.65%</td>
</tr>
<tr>
<td>Queens</td>
<td>50,952</td>
<td>124</td>
<td>0.24%</td>
</tr>
<tr>
<td>Manhattan</td>
<td>28,511</td>
<td>287</td>
<td>1.01%</td>
</tr>
<tr>
<td>Bronx</td>
<td>21,591</td>
<td>22</td>
<td>0.10%</td>
</tr>
<tr>
<td>Westchester</td>
<td>16,109</td>
<td>21</td>
<td>0.13%</td>
</tr>
<tr>
<td>Staten Island</td>
<td>7,786</td>
<td>73</td>
<td>0.94%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>178,600</strong></td>
<td><strong>877</strong></td>
<td><strong>0.49%</strong></td>
</tr>
</tbody>
</table>
### Confirmed Stray Voltage Levels

<table>
<thead>
<tr>
<th>Stray Voltage Level (volts)</th>
<th>Number in Range</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 8</td>
<td>363</td>
<td>41.4</td>
</tr>
<tr>
<td>9 to 20</td>
<td>298</td>
<td>34</td>
</tr>
<tr>
<td>21 to 50</td>
<td>161</td>
<td>18.4</td>
</tr>
<tr>
<td>Over 50</td>
<td>55</td>
<td>6.3</td>
</tr>
<tr>
<td>Total</td>
<td>877</td>
<td>100</td>
</tr>
</tbody>
</table>
Key Causes of Stray Voltage on Streetlights

• 96% of All Energized Locations are Associated with Streetlights (877 Events in 2006)
• 53% are caused by bad connections in lamp bases
• 46% are due to failed Con Edison phase conductors or failed neutrals in the metal conduit
• 1% other
Streetlight (underground system)

Con Edison and DOT responsibilities
Streetlight
(underground system – base detail)
Streetlight Isolation Transformers
Streetlight Isolation Transformers

• R&D Effort
• Con Edison Purchased 5,000 units
• 600 VA Rating
• Medical Grade UL 60601-1
Isolation Transformer Theory
No Circuit – No Shock

Con Edison Service

Isolation Transformer

Streetlight Wiring
Streetlight SafeTap
Open Lamp Base

Look for Fuse Holders
**Make Connections**

**Step 1)** Disconnect existing fuse

**Step 2)** Connect Safe Tap Ground (*Green*) and Neutral (*White*) to conducting lamp base or bonding bushing

**Step 3)** Connect Safe Tap fuse holder (*Red*) to StreetLight fuse (Black) with 15A fuse

**Step 4)** Connect Safe Tap fuse holder (Black) to Utility Service (Black) with 30A fuse
Safe Tap in Operation

Fan connected and blowing

20A max for each outlet
Remove Safe Tap Connection

Step 1)
Disconnect Utility Service (black) fuse holder and Safe Tap (black) fuse holder

Step 2)
Disconnect remaining Safe Tap connections

Step 3)
Reconnect streetlight Connections with 15A fuse for fuse holder

Remember to retain the Safe Tap fuse for later use!
Secure Lamp Base

6 Minutes from Start to Finish
Benefits of Streetlight Safetap®

• Provides a quick, convenient source of 120 volt temporary power from streetlights using existing fuseholders
• No need to run expensive, noisy, and polluting generators or inverters
• Increases safety by eliminating cutting and handling of bare energized conductors
• No special training required to make connections
PhaseSaver Toroidal Autotransformer
Purpose

• To safely provide three conductor service to a customer when a single phase of the underground service fails (without installing an overhead temporary service or bridging in the customer panel)
Shunt Transformer (Currently Used)

Dry Pack

15kVA - $2200 – 250 lbs
25kVA - $2450 – 350 lbs
(vs. autoXFMR $600, 53 lbs)

- Can’t fit in most vehicles
- Heavy, burdensome
Single Open Phase
First Test
Powering a 240V Air Conditioner from a 120V Outlet
Second Test
Meter & Test Office
Third Test
Company MCC-1 Bus
Fourth Test
Installation on 21-35 35\textsuperscript{th} Street
Fifth Test
36,000 BTU Network AC Unit
Design Specifications

- 8000 VA
- Weight 53 lbs
- Dimensions (14” tall X 11” wide X 4.5” deep)
- Thermal Switch Autotrip with overload light
- Green lamp indicates power to unit
PhaseSaver Toroidal Autotransformer
Applications

• House Service Failures
• Con Edison Command Center Bus MCC-1
• Police Surveillance Vans / Mobile Office Trailer
• Network Transformer Air Conditioners
• Parked Refrigerated Trucks
MainsTap
Challenge

• Provide a safer method of tapping service mains for shunts and temporary power
• Reduce need to repeatedly cut and seal cable insulation
Split Bolt Connector for Shunt
Primary Live-End Cap (LEC)
If We Can Make a Primary Live End Capped Connector, Why Can’t We Make a Secondary Live End Cap?
MainsTap (tee version)
MainsTap (straight version)
MainsTap (elbow version)
Removable Boots for MainsTap
Field Test
Field Test (Cont’d)
Feedback from #9 Emergency Bureau and I&A Services

• Include more ribbing surface
• Develop a flexible, removable boot
• Use captive nuts/check wrench clearances
• Develop In-Line/Elbow Versions
• Consider use with generators
• Would reduce damage to system from repeated cutting and re-sealing cable and need for Burndy® Split Bolt Connectors
Next Steps

• Standards Committee Reviews
• Lab Testing – Mechanical and Severe Heat Runs
• Training
• Issue Bulletin
• Class and Stock
Contacts - For More Information

- Al Homyk   (718) 204-4175
- Don Lucia  (718) 204-4412
- Randy Auclair – Electric Motion Company (860) 379-8515
- Ulrik Poulsen – Bridgeport Magnetics/Tortran (203) 335-6805
Questions?
Swimming Pools

2008 National Electrical Code Changes

Article 680.26
Frank C. Lambert
404-675-1855
frank.lambert@neetrac.gatech.edu
DEFINITIONS  2005 NEC – Article 100

• Bonding (Bonded). The permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to conduct safely any current likely to be imposed.

• Grounded. Connected to earth or to some conducting body that serves in place of the earth.
• 1959 NEC – No mention of swimming pools.

• 1962 NEC – Article 680 – Swimming Pools
  
  • 680-7 Grounding.
    – (a) All metallic conduit, piping systems, pool reinforcing steel, lighting fixtures, and the like, shall be bonded together and grounded to a common ground. The metal parts of ladders, diving boards, and their supports, shall be grounded.

  • 680-8 Methods of Grounding and Bonding
    – (c) Non-electrical equipment required to be grounded to a common ground in accordance with Section 680-7 shall be grounded in accordance with Article 250.
    – Structural reinforcing steel may be used as a common bonding conductor for non-electrical parts where connections can be reliably made in accordance with the provisions of Article 250.
• 1975 NEC – Renumbering of Sections – Bonding and Grounding are now clearly separate issues.

• 680-22 Bonding
  (a) The following parts shall be bonded together:…
  (b) These parts shall be connected to a common bonding grid with a No. 8 solid, copper conductor and connection shall be made in accordance with Section 250-113. The common bonding grid may be any of the following.
  – (1) The structural reinforcing steel of a concrete pool where the reinforcing rods are bonded together by the usual steel tie wires or the equivalent; or,
  – (2) The wall of a welded metal pool; or,
  – (3) A solid, copper conductor not smaller than No. 8.

• 680-24 Grounding
• 1984 NEC – A very significant change / clarification added a fine print note mentioning the purpose of bonding is to eliminate voltage gradients in the pool.

  (FPN): It is not the intent of this subsection to require that the No. 8 or larger solid copper bonding conductor be extended or attached to any remote panelboard, service equipment or any electrode, but only that it be employed to eliminate voltage gradients in the pool area as prescribed.

• 1987 through 1996 – Only minor changes.

National Electrical Code Development

• 1999 NEC – Article 680-22.
  • The NEC Handbook had the following comment: The primary purpose of bonding is to ensure that voltage gradients in the pool area are eliminated.
  • The revised wording of Section 680.22 in the 1999 Code makes it clear that the No. 8 conductor is only for the elimination of the voltage gradient in the pool area and is not required to provide a path for fault current that may occur as a result of electrical equipment failure.

• 2002 NEC – Sect. 680.22 was changed to 680.26. Elimination of voltage gradients was made even stronger.
• 2005 NEC renamed Article 680.26 Equipotential Bonding
  • Added part (C) Equipotential Bonding Grid to 680.26.
  • The equipotential common bonding grid shall extend under paved walking surfaces for 1 m (3 ft) horizontally beyond the inside walls of the pool and shall be permitted to be any of the following:
    (1) Structural Reinforcing Steel. The structural reinforcing steel of a concrete pool where the reinforcing rods are bonded together by the usual steel tie wires or the equivalent.
    (2) Bolted or Welded Metal Pools. The wall of a bolted or welded metal pool.
(3) Alternate Means. This system shall be permitted to be constructed as specified in (a) through (c):

− a. Materials and Connections. The grid shall be constructed of minimum 8 AWG bare solid copper conductors.

− b. Grid Structure. The equipotential bonding grid shall cover the contour of the pool and the pool deck extending 1 m (3 ft) horizontally from the inside walls of the pool. The equipotential bonding grid shall be arranged in a 300 mm (12 in.) by 300 mm (12 in.) network of conductors in a uniformly spaced perpendicular grid pattern with tolerance of 100 mm (4 in.).

− c. Securing. The below-grade grid shall be secured within or under the pool and deck media.

• Note: See Temporary Interim Agreement 05-2 for revisions to this section (exception to the bottom or sides of a nonconductive pool).
PROBLEM

• 2005 NEC Article 680.26 covers bonding of metal parts in and around swimming pools to an equipotential bonding grid.

• The article assumes that one or more of the parts are in contact with the pool water.

• Some pools do not have any bonded metal parts.

• Water-deck voltages may be significant for such a pool.
PROBLEM & SOLUTION

ACTUAL CASE

• An employee of a member company installed a one piece drop-in pool.

• An equipotential ground grid was installed around the pool as per NEC 2005.

• 1.7 to 2 volts was measured between the pool water and ground ring.

• A copper butt plate connected to a #8 copper wire was dropped in the water (see Figure).

• Upon bonding the copper butt plate in the water with the ground grid, the voltage differential went to zero.
APPROACH

- NEETRAC and a member company designed a field project to measure water-deck voltages at an existing swimming pool with a history of customer complaints.

- The project mitigated the customer’s problem and allowed NEETRAC to measure water-deck voltages for various bonding scenarios in support of Article 680.26 and the proposed solution.
POOL DESCRIPTION

- Hole in the deck to connect or disconnect the light from the ground
- Underwater light
- Ground ring lying on the concrete
- AWG #6 solid copper ground ring with seven ground rods driven at angle
- 120-volt electrical box serving the underwater lights
- Jacuzzi with an underwater light
- Wetland
CUSTOMIZED TEST SETUP TO RAISE VOLTAGE GRADIENTS AROUND THE POOL

Test Connections

120V to 40V Transformer

Line - Black
Neutral - White
Ground - Bare

To Main Pool Light in Conduit

To Jacuzzi Light in Conduit

Line - Black
Neutral - White
Ground - Green

Line - Black
Neutral - White
Ground - Green

VNE Connect to ground ring or pool light frame

Remote Driven Ground Rod

100 feet

House

Access Hole

Pool

Buried #6 Copper Ground Ring

Jacob

Disconnect Switch A
- Test Connections

Neutral - White
Ground - Bare

120V to 40V Source

Test Connections

Jodie Lane National Conference for Stray Voltage Detection, Mitigation, and Prevention
June 5, 2007
#6 Copper Ground Ring on top of Deck

Flexible PVC Conduit to Switch A
Black, White, Green

Ground Rod

#6 Bare Copper to Pool
Light Frame

Flexible PVC Conduit to Pool Light
Black, White, Green

Jodie Lane National Conference for Stray Voltage Detection, Mitigation, and Prevention
June 5, 2007
WATER-DECK MEASUREMENT LOCATIONS AROUND THE POOL

Pool & Jacuzzi Light Disconnect Switch

Conduits to Lights

#6 Copper Ground Ring on top of Deck

Access Hole

Underwater Light

Buried #6 Copper Ground Ring

House

Grass

Ground Rods

Pool

Jacuzzi

Deck

Conduits to Lights
THREE BONDING SCENARIOS PERTAINING TO ARTICLE 680.26 AND THE PROPOSED SOLUTION

1. Pool light and water are bonded. Ground ring and rods are not bonded.

2. Pool light, water, ground ring and rods are bonded. (2005 NEC 680.26 requirement)

3. Pool and water are not bonded but ground ring and rods are bonded. (Problem with Article 680.26 when there is no metallic bond to the pool water.)
TEST DATA

Water-Deck Voltages along Location E

Distance from Pool Water (Feet)

Water-Deck Voltage (% of Vne)

- Water Bonded
- Water & Ring Bonded
- Ring Bonded
TEST DATA

Water-Deck Voltages along Location F

Distance from Pool Water (Feet)

Water-Deck Voltage (% of Vne)

Ground

Ring

Water Bonded

Water and Ring Bonded

Ring Bonded

Jodie Lane National Conference for Stray Voltage Detection, Mitigation, and Prevention
June 5, 2007
TEST DATA

Water-Deck Voltages along Location G

Distance from Pool Water (Feet)

0 2 4 6 8 10 12 14

0 20 40 60 80 100 120

Water-Deck Voltage (% of Vne)

Ground
Ring

Water Bonded
Water & Ring Bonded
Ring Bonded
TEST DATA

Water-Deck Voltages along Location H

Distance from Pool Water (Feet)

Water-Deck Voltage (% of $V_{ne}$)

Ground Ring

Water Bonded

Water & Ring Bonded

Ring Bonded
ANALYSIS

• Blue graph (only pool water bonded)
  • Water – deck voltage rises almost 100% within one foot distance due to an insulated pool lining.
  • From one foot distance onward, the voltage practically remains the same.
  • As expected the maximum voltage gradient occurred across the insulated liner of the pool.
ANALYSIS (Continued)

• Red graph (pool water and ground ring bonded)
  • The proposed change to Article 680.26 requiring intentional bonding of pool water.
  • The equipotential bonding of the water to the ground ring reduced the water-deck voltage from 95% (Blue Graph) to 40% near the water.
ANALYSIS (Continued)

- Green graph (only ring bonded)
  - Present requirement of NEC Article 680.26.
  - Water-deck voltages increase to almost 100% as they approach the ground ring.
  - Since the ground ring is located at a distance of 11.5’ from the water, the voltage gradients near the water are not significant in this investigation.
  - Voltages near the water will increase significantly if the ground ring or a hand rail were to be located near the water.
PROJECTED WATER-HANDRAIL VOLTAGES BASED ON MEASURED DATA
Insert a new Section 680.26(C) as follows:
680.26 (C) Pool Water

An intentional bond of a minimum conductive surface area of 5806 mm² (9 in²) shall be installed in contact with the pool water. This bond shall be permitted to consist of parts that are required to be bonded in 680.26(B).

Renumber the present Sections sequentially from (C) to (D), (D) to (E), and (E) to (F).
IEEE Working Group on Voltages at Publicly and Privately Accessible Locations

June 5th 2007

Doug Dorr – EPRI
IEEE Working Group on Voltages at Publicly and Privately Accessible Locations

This working group was formed at the joint request of the PES Distribution Subcommittee members and the IEEE T&D Committee.

The purpose of the working group is to write a trial-use guide for assessing voltages at publicly and privately accessible locations. The proposed guide may include some or all of the following topics:

- Definitions
- Causes
- Testing protocols
- Measurement Equipment
- Mitigation options
- Applicable codes and standards
- Levels of concern

Officers

**Chair**  
Chuck DeNardo  
WE Energies  
333 West Everett Street  
Milwaukee, WI 53202  
USA  
Chuck.DeNardo@we-energies.com

**Vice Chair**  
Jim Bouford  
National Grid USA Service Company  
55 Boardfoot Road  
Northborough, MA 01532  
USA  
james.bouford@us.ngrid.com

**Secretary**  
Russ Ehrlch  
Connectix  
Mailstop 709082  
Newark, DE 19714-6065  
USA  
russ.ehrlch@connectix.com

Next Meeting

The working group regularly meets with the IEEE Distribution Subcommittee. See the the schedule for the subcommittee’s next meetings.

Next Web Meeting

There will be a web meeting of the working group starting at 11:00 AM (Eastern Time) on May 17, 2007. The topics for the meeting include:

- "Swimming Pool Equipotential Bonding - Proposed Changes to NEC 660.26," a presentation by Shashi Patel of NEETRAC. The presentation includes field test data and recommendations made to NEC Code Panel 17 that would require "an intentional bond in contact with the pool water,"
- Discussion of proposed outline for the working group's Trial Use Guide in hopes of writing a draft outline for discussion at the next working group meeting in Tampa.

If you want to participate, contact the working group chair Chuck DeNardo at Chuck.DeNardo@we-energies.com for information on how to participate in the meeting.

Meeting Minutes

- June 2006, Montreal
- January 2006, Las Vegas
- July 2005, San Francisco

Draft Definitions

- Stray Voltage Definition (256x)
There will be a web meeting of the working group starting at 11:00 AM (Eastern Time) on May 17, 2007. The topics for the meeting include:

- "Swimming Pool Equipotential Bonding - Proposed Changes to NEC 600.26," a presentation by Shashi Patel of NEETRAC. The presentation includes field test data and recommendations made to NEC Code Panel 17 that would require "an intentional bond in contact with the pool water."
- Discussion of proposed outline for the working group's Trial Use Guide in hopes of writing a draft outline for discussion at the next working group meeting in Tampa.

If you want to participate, contact the working group chair Chuck DeNardo at chuck.denardodwe-energies.com for information on how to participate in the meeting.

Meeting Minutes

- June 2006, Montreal
- January 2006, Las Vegas
- July 2006, San Francisco

Draft Definitions

- Stray Voltage Definition (254KB)

Web Meeting Presentation, November 2006

- Meeting Presentation (2.81MB)

Dallas Panel Session Presentations, May 2006

- Stray Voltage Survey, CEATI (1.42MB)
- Suggested Terminology, Jim Boufor (286KB)
- Stray Voltage Issues, Ken Doster and Jim Burke (358KB)
- "Was the Stray Voltage Really Straight", Charlie Williams (220KB)
- Overview of EPRI Experience, Doug Don and Charles Perry (516KB)
- Elevated NYD due to Third Harmonic, Randy Collins and John Jang (390KB)
- Induced Stray Voltages from Transmission Lines, Shashi Patel and Frank Lambert (378KB)

Web Meeting Presentation, April 2006

- The Grounding of Power Systems Above 600 Volts: A Practical Viewpoint (439KB)

IEEE/PES Winter Technical Committee Meeting, January 2006

- Stray Voltage: Legislative and Regulatory Activity (62KB)

Discussion Forum

- Enter Forum hosted by EPRI Solutions

This page is maintained by Dan Sabin and was last updated on April 25, 2007.
The Grounding of Power Systems Above 600 Volts: A Practical Viewpoint

John P. Nelson
Fellow, IEEE
NEI Electric Power Engineering
Arvada, CO

This Web cast will have two parts:

Graciela Varela-Maloney: Consolidated Edison’s Program for Detection and Mitigation of Stray Voltage

Chuck DeNardo: Do We Have Big Picture Consensus? Can we move forward?

Questions at any time during the presentation.

Please mute your phones when not speaking.

“Stray Voltage” Legislative and Regulatory Activity

IEEE Winter Technical Committee Meeting
January 16, 2006
Las Vegas, Nevada

Chuck DeNardo
Principal Engineer
We Energies
(chuck.denardo@we-energies.com)

Stray voltages

Survey of the different stray voltage practices from different utilities and under different jurisdictions in North America

May 2006
OUTLINE DRAFT

Trial Use Guide for Assessing Voltages at Publicly and Privately Accessible Locations

From the Standards Board Operations Manual:

• **Guides**: documents in which alternative approaches to good practice are suggested but no clear-cut recommendations are made.

• **Trial-Use documents**: publications that are effective for not more than two years.
P1695 PURPOSE

There is presently no industry wide guide or standard that describes the variety of publicly and privately accessible voltages resulting from the delivery and use of electrical energy. This guide will help dispel misinformation surrounding this topic and enhance public safety.
P1695 SCOPE

This guide addresses the normal and abnormal voltages that exist at publicly and privately accessible locations as a result of the delivery and use of electrical energy (often referred to as stray voltage). It focuses primarily on the presence of power frequency related voltages, and discusses definitions, causes, impacts, testing techniques, mitigation strategies, and hazard levels.
From the Scope of P1695

Normal and Abnormal Voltages

That Exist at Publicly and Privately Accessible Locations

As a Result of the Delivery and Use of Electrical Energy

Focuses Primarily on the Presence of Power Frequency Related Voltages

Discusses Definitions, Causes, Impacts, Testing Techniques, Mitigation Strategies, and Hazard Levels
That Exist at **Publicly Accessible** Locations

- Lamp post to sidewalk voltage
- Pad mounted equipment to earth voltage
- Manhole cover to street surface voltage
- Water fountain to earth voltage
That Exist at **Privately Accessible** Locations

Animal contact voltage (private barn)

Water faucet to earth voltage (private back yard)

Pool water to pool apron voltage

**That Are Not Accessible:**

Properly insulated phase conductors
Voltagess found within any electrical enclosure
Voltagess found within any substation, manhole, or vault

_________________________  wgovapapal  __________________________
At some point we have to agree on the terms and definitions that will be used to describe the normal and abnormal publicly accessible voltages covered in the proposed Trial Use Guide.

In order to avoid confusion as we move forward in this discussion I propose we temporarily use the following terms:

**Stray Voltage** - Voltages that are the result of normal system operation (caused by return and induced currents).

**Contact Voltage** - Voltages that are the result of abnormal system operation (caused by fault currents).
A Few Important Points
(Based On Working Group Discussions To Date)

There are publicly accessible voltages related to normal system operation that must be present, and there are publicly accessible voltages related to abnormal system operation that should not be present. These are two very different things that should be defined and discussed separately.

Human and animal exposure to conducted current is well understood. We want the reader to learn something about the science behind existing exposure standards; where to find, and how to apply these standards. This is necessary so that informed decisions can be made regarding the degree of hazard that exists and what, if anything, should be done about it.

We want to provide the reader with the knowledge and tools necessary to make meaningful measurements. This will enable identification of sources and, if necessary, aid in selection of appropriate mitigation alternatives.
General Objectives

To facilitate a better understanding of the causes, investigation procedures and mitigation options for voltage concerns at publicly and privately accessible locations

- Human and animal physiological responses to currents through the body
- Identification of the various sources of stray voltages to include induced voltages on to metallic objects, grounded neutral conductors, and high impedance power system and load faults
- Standardized measurement protocols and procedures to characterize the various sources and types of stray voltage
- Proposed voltage levels for the various situations (pools, pipelines, manhole covers etc.) upon which remedial actions should be pursued
1. Overview (Required)

2. Normative References (Required)

3. Definitions/Acronyms/Abbreviations (Required)

4. General Discussion

5. Human and Animal Sensitivity to Conducted Current
   5.1 Sensitivity in terms of voltage exposure

6. Publicly and Privately Accessible Voltages Related to Abnormal System Operation ("Contact Voltage")
   6.1 General
   6.2 Contact Voltage Sources
   6.3 Contact Voltage Investigation
      6.3.1 Test and Measurement Equipment
      6.3.2 Investigation Protocol
   6.4 Contact Voltage Mitigation
   6.5 Case Studies
7. Publicly and Privately Accessible Voltages Related to Normal System Operation ("Stray Voltage")
   7.1 General
   7.2 Stray Voltage Sources
      7.2.1 Return Current
      7.2.2 Induced Current
   7.3 Stray Voltage Investigation
      7.3.1 Test and Measurement Equipment
      7.3.2 Investigation Protocol
         7.3.2.1 Confined Livestock
         7.3.2.2 Swimming Pools
         7.3.2.3 Outdoor and Basement Showers
   7.4 Stray Voltage Mitigation
   7.5 Case Studies

8. Previously Established Voltage Exposure Standards

9. Existing Regulation

   Annex A: Flow Charts

   Annex B: Sample Data Collection Forms

   Annex C: ???
Outline Draft (05/17/2007)

IEEE Trial Use Guide for Assessing Voltages at Publicly and Privately Accessible Locations

1. Overview (Required)
   Scope and Purpose of the Guide

2. Normative References (Required)
   Documents necessary to understand and use the Guide (e.g. USDA Handbook 696)

3. Definitions/Acronyms/Abbreviations (Required)

4. General Discussion
   Reasons for confusion surrounding the issue, some amount of measurable voltage will always be present, contact voltage v. stray voltage, sources are both primary (utility) and secondary (customer), grounded v. ungrounded systems, etc.
Outline Draft (05/17/2007) Continued

IEEE Trial Use Guide for Assessing Voltages at Publicly and Privately Accessible Locations

5. Human and Animal Sensitivity to Conducted Current

Research summary, nerve stimulation model discussion, factors affecting sensitivity, sensitivity versus frequency and/or duration of exposure, people versus animals, etc.

5.1 Sensitivity in terms of voltage exposure

Characteristics and importance of the exposure circuit (e.g. source impedance, contact impedance, body impedance, etc.), why it’s difficult to create a voltage exposure standard, etc.
Outline Draft (05/17/2007) Continued

IEEE Trial Use Guide for Assessing Voltages at Publicly and Privately Accessible Locations

6. Publicly and Privately Accessible Voltages Related to Abnormal System Operation (“Contact Voltage“)

6.1 General

Potentially hazardous nature of contact voltage, degree of hazard dependent on exposure circuit not measurement circuit, number of incidents (i.e. putting the issue in perspective), existing proactive programs, etc.

6.2 Contact Voltage Sources

Fault current (i.e. shorts and opens), fault current availability, insulation degradation, wiring errors, broken conductors, voltages induced during fault conditions, etc.
IEEE Trial Use Guide for Assessing Voltages at Publicly and Privately Accessible Locations

6.3 Contact Voltage Investigation

6.3.1 Test and Measurement Equipment
Electric field detection (e.g. proximity detectors, mobile platforms, etc.), multi-meters, load resistors, safety gear, etc.

6.3.2 Investigation Protocol
Safety precautions, understanding remote earth, measurement location, measurement technique, data analysis, false positives, etc.

6.4 Contact Voltage Mitigation
Insulation failure, wiring errors, open conductors, etc.

6.5 Case Studies
Street light, manhole, etc.
IEEE Trial Use Guide for Assessing Voltages at Publicly and Privately Accessible Locations

7. Publicly and Privately Accessible Voltages Related to Normal System Operation (“Stray Voltage”)

7.1 General

Historically considered a nuisance voltage. Generally associated with animal exposures, swimming pool & shower shocks. Primary (utility) and secondary (customer) sources. Harmonics, transients, etc.

7.2 Stray Voltage Sources

7.2.1 Return Current

Systems with a neutral conductor, systems without a neutral conductor, SWER, etc.

7.2.2 Induced Current

Transmission Source, Primary Source, Secondary Source, etc.
7.3 Stray Voltage Investigation

7.3.1 Test and Measurement Equipment

Recording devices, load boxes, copper plates, etc.

7.3.2 Investigation Protocol

7.3.2.1 Confined Livestock

7.3.2.2 Swimming Pools

7.3.3.3 Outdoor and Basement Showers

7.4 Stray Voltage Mitigation

Bad neutral connections, undersized conductors, poor grounding, phase balance, system voltage, etc.

7.5 Case Studies
Outline Draft (05/17/2007) Continued

IEEE Trial Use Guide for Assessing Voltages at Publicly and Privately Accessible Locations

8. Previously Established Voltage Exposure Standards
   IEEE, IEC, NEC, etc.

9. Existing Regulation
   Wisconsin, Idaho, Michigan, New York, etc.

Annex A: Flow Charts

Annex B: Sample Data Collection Forms

Annex C: ???
IEEE P1695 WG Next Meeting

Monday, June 25, 2007
13:00-16:00
Stray Voltage WG

2007 PES GENERAL MEETING
24-28 June

Tampa Convention Center
333 S. Franklin Street
Tampa, Florida 33602 USA

Marriott Waterside Hotel
700 S. Florida Ave
Tampa, Florida 33602 USA

The Registration site for the General Meeting is now open and can be accessed at www.pesmgmt.org. A brief listing of registration fees is available in the registration section of this page. Note: IEEE PES has instituted a modest charge for advance ($30) and on-site registration ($45) for life members and life member Registered Companies, which matches the student fees for GM 2007.

We are accepting applications for the 2007 IEEE PES General Meeting Student Housing Program and Entries for the Poster Contest starting March 1, 2007. Please visit http://ee.ai/en02-07/ for more information. For questions, please contact Prof. Vidishu Misra (misra@ecnu.edu), Prof. William Bills (wibills@ecnu.edu) or Ganesh Kumar Venayagamoorthy (gkumar@ece.ufl.edu) at IEEE PES.
EPRI Program 128.004
Elevated NEV and Urban Stray Voltage Concerns in Distribution Systems Research Update

June 5th 2007
Doug Dorr – EPRI
P128.004 Elevated NEV and Urban Stray Voltage Concerns

- This project has been ongoing since 2004 to address gaps in the research and technology transfer.
- In 2007 the project provides sponsors with informational support (for regulators and customers):
  - Standardized measurement protocols (best practices and more accurate documentation)
  - Investigation support (reduces trouble crews time)
  - Case studies (helps investigators with location of problem and solution options)
  - Industry outreach – IEEE, Pool and spa mfrs. association (helping to promote standardization and better grounding and bonding practices)

2007 Jodie Lane National Conference for Stray Voltage Detection, Mitigation & Prevention
Five Focus Areas

– Measurement of Contact Voltage
– Modeling and Simulation
– Diagnostics and Mitigation
– Mitigation Devices and Condition Assessment
– Regulatory Informational Support and Technology Transfer
Specific Focus Area Needs

– Measurement of Contact Voltage
  - Are the investigative tools we use today adequate?
  - What are some areas of opportunity for new tool development?
  - Can we use existing monitoring devices to support early detection efforts?

– Modeling and Simulation
  - What parameters impact contact voltages? Which are most important?
  - Is it possible to model entire distribution systems?
  - What kinds of accuracies should be expected?

– Diagnostics and Mitigation
  - Better ways to quickly identify the source(s)
  - Prioritization based on the type of contact voltage concern
  - Better likelihood the correct mitigation solutions get applied
Specific Focus Area Needs

– New Mitigation Techniques and Condition Assessments
  - Based on the source(s)
    - Are there alternative mitigation solutions
    - What is considered “Typical” or “Normal”?
– Regulatory Recommendations and Information Transfer
  - Accurate and factual information for informed decision making
  - Clear understanding of the differences in contact scenarios and the objective: (aversion, injury due to startle reaction, let go thresholds, etc.)
P128.004 Elevated NEV and Urban Stray Voltage Concerns

- EPRI Sponsored Project Website – 2007 Updated Version will be on line August 2007
- Provides information to sponsors and the public to promote credible and unbiased information on the subject matter

Elevated Neutral to Earth Voltages
An EPRI research project to evaluate neutral to earth voltage concerns and solutions on distribution systems.

EPRI Program 128.003

Welcome to the "Evaluation of Impacts and Mitigation Techniques for Neutral to Earth and Stray Voltage Sources" web page. Here you will find information pertaining to the EPRI research project. Project results are have restricted access to project participants only. If you are a project participant and do not have access to the results, please contact Chris Methum for a username and password.
P128.004 Elevated NEV and Urban Stray Voltage Concerns

Key results from 2006
- Final report describes software, procedures and examples on how different changes to resistances, impedances and capacitor bank configurations impact NEV levels
- Findings: With careful field measurement verification, we can expect accurate (plus/minus 10%) modeling results to evaluate distribution level parametric

Project 2007 Objectives
- Evaluate sponsor selected measurement equipment or mitigation devices to support a comprehensive NEV and Urban Stray Voltage Investigators Toolbox
- Via Website - Provide comprehensive and technically accurate materials to support investigations and understanding of mitigation options
- Support ongoing IEEE “contact voltage” standards efforts
- Provide credible data on typical NEV levels for feeders and circuits to better define regulator expectations regarding grounded neutral circuits
P128.004 Elevated NEV and Urban Stray Voltage Concerns

Task 1 – Evaluate measurement and mitigation equipment
- Testing will be accomplished in controlled laboratory setting or at field site depending on the device
- Deliverables will be technically accurate application guidance and expectations documents
- Some field sites may be evaluated by equipment

Task 2 – Website
- Update existing information to reflect 2007 level of understanding
- Provide more application guidance on use of test and measurement equipment
- Provide more application guidance on mitigation solutions

Task 3 – NEV levels technical assessment
- Field measurements
- Controlled laboratory measurements on representative circuits
Conclusions

- The EPRI Efforts and the IEEE Efforts are closely aligned in terms of developing consistent and repeatable investigation and remediation guidelines.
- EPRI’s efforts are intended to supplement but not duplicate any of the other research.
- The subject continues to gain support and the number of participating electric service providers has increased significantly.
Roundtable Discussion

Issues and Potential Follow-on Actions
June 5th 2007
Frank Doherty – Session Moderator
Roundtable Format

1. ~20 minutes each (dependent on number)
2. One person will briefly describe the concern
3. Participants will provide:
   1. Specific issues
   2. State of the art and present published work
   3. What others are doing
   4. What is needed
4. Moderator will summarize actions & follow-up
Discussion Topics

1. Degraded concentric neutrals
2. Transmission structure testing
3. New test and measurement tools
4. Items from participants
Roundtable Discussion

Degraded Concentric Neutrals
Elevated Neutral - to - Earth Voltage

Forest Bigenho – Snohomish PUD
ffbigenho@snopud.com
June 5, 2007
Presentation Overview

- Utility Background
- System Configuration
- Problem
- Troubleshooting
- Resolution
PUD Service Territory

Headquarters:
2320 California Street, Everett, WA 98201
(Mailing Address: PO Box 1107, Everett, WA 98206-1107)

2007 Jodie Lane National Conference for Stray Voltage Detection, Mitigation & Prevention
Electric System

- **Service Area:** 2,200 square miles, including all of Snohomish County and Camano Island
- **2006 Electrical Service Connections:** 7,760
- **2006 Average Number of Employees:** 900
- **2006 Energy Sales:** 8,167,281 megawatt-hours
- **2006 Electric System Operating Revenues:** $582,847,000
- **Generating Capacity:** 164 megawatts (Jackson Project, Everett Cogeneration Project)
- **Residential Rate:**
  - 7.7¢ per kilowatt-hour (April 1 - September 30)
  - 8.0¢ per kilowatt-hour (October 1 - March 30)
PUD Customer Categories

- **INDUSTRIAL:** 77 customers
- **COMMERCIAL:** 27,270 customers
- **OTHER:** 477 customers
- **RESIDENTIAL:** 272,829 customers
Operating Voltages

- Transmission 115 kV
- Distribution 12.47 kV
  - Overhead/Underground Radial & Looped Radial
- OH/UG Secondary Service voltage
  - 120/240 Volt Single Phase
  - 240/480 Volt Single Phase (UG max 100kVA)
  - 120/208 Volt Single/Three Phase
  - 277/480 Volt three Phase Wye
Underground Distribution

- Direct Buried ~ 800 miles (Early 60’s – Late 80’s)
- Conduit/Ducts ~2400 miles (PVC/Fiberglass/Steel)
- Conductor Insulation Types:
  - XLPE
  - TRXLPE (1985 to present)
  - EPR (1000kcmil only)
- Conductor Splicing
  - Straight Splice only…Junction Boxes used for 3 and 4 way conductor configurations.
UG CABLE PROGRAM

- Development/Design for new construction/area development (2000 to 2006 growth rate at 11%)
- Managing 800 miles of direct-buried distribution cable
- Prioritizing cable re-conductor/cable rejuvenation
  (cable rejuvenation via silicone injection)
- Yearly goal: Replace 20 miles of UG conductor
  Rejuvenate 40 miles of UG conductor
Elevated Neutral to Earth Voltage (NEV)

- Condition at (camping-park) revealed high (NEV) values (12.47/7.2 kV – Single phase dist.)
- Conductor Direct Buried unjacketed XLPE – 30+ Svc Years
- TDR (Time Domain Reflectometer) demonstrated bad/open concentric neutrals.
- Poor area grounding
- Seasonal Loading
Camp Ground/Trailer Park
Troubleshooting

- Research utility records and maps *(when & what is installed)*
- Validate complaint *(voltmeter between shower head/drain)*
- Inspect customer service terminations/grounds
- Inspect utility transformer grounding and concentric neutral cable conditions
- Review loading *(what loads applied)* rule out harmonics
- Perform Time Domain Reflectometer test.
- Perform Conductor to Soil Potential test.
- Sent Soil samples to Lab *(help determine rate of corrosion)*
Underground Cable
TDR Feed
Underground Cable TDR Reflections
Underground Cable
TDR Reflections

TDR plot of underground cable with splice – no neutral corrosion
Underground Cable
TDR Reflections

TDR plot of underground cable with level 3 neutral corrosion
Conductor to Soil Potential Test
Pot Hole - Soil Snap Shot
Planned Action/Resolution

- Identify cables with deteriorated neutrals
- Replace with TRXLPE jacketed type cable in conduit
- Install new earth grounding system at each vault – (grounds will be enhanced due to very rocky soil)
- Possibly install corrosion mitigation system for remaining cable – cathodic protection.
- Remaining cable to be replaced on a planned schedule
Questions

What are other utilities doing for the following:

- Neutral Corrosion identification
- Corrosion mitigation – cathodic protection
- Cable Replacement
- Cable Injection
- Comprehensive underground cable management program
- Prioritizing cables for injection and replacement
Roundtable Discussion

Transmission Structures
Testing for Stray Voltage
Transmission Structures
Transmission Structures

Transmission lines present several different configurations for towers, overhead wires and tower footings (counterpoise).

The different configurations will establish different responses of the system; whether stressed by lightning, or steady state in conjunction with other linear or spot structures, such as electric distribution lines (OH or UG), gas mains, fences etc.
Transmission Structures

1. Specific issues
2. State of the art and present published work
3. What others are doing
4. What is needed
Roundtable Discussion

Development of New Tools
To Diagnose and Resolve
Stray Voltage Source(s)
New Tools Issues

- Different Sources
  - Magnetically Coupled
  - Faulted Objects
  - Multi Grounded Neutrals

- Different Levels of Concern
  - Aversion (perception)
  - Injury (startle reaction)
  - Injury (let go threshold)
Today’s Situation

- Lots of tools from pen lights to data loggers – none overly simple to use
- Not easy to diagnose the source without detailed assessment
- Minimal number of tools for early detection
  – (early as in before the shock complaint call)

Perspective from an equipment manufacturer?
New Tools

1. Specific issues
2. State of the art and present published work
3. What others are doing
4. What is needed
Cable and Splice Center for Excellence
• Welcome and Introduction
• Failure Analysis Lab
• Diagnostics Lab
• Electrical Testing Area
• Mobile Stray Voltage Detection Vehicle
Why a Cable and Splice Center for Excellence?

• Extensive Distribution System
• Repair / Replace strategies
• Aging Infrastructure
• Peer Consensus
• Information Sharing
• Diminishing Expert Pool
Optimize Repair / Replace Strategies

• Prioritize replacement decisions
  • PILC cable replacement primary focus

• Optimize feeder repairs
  • Primary burnouts
Why a Cable and Splice Center for Excellence?

Peer Consensus

No consensus within the technical expert community regarding failure causes or diagnostic techniques.
Why a Cable and Splice Center for Excellence?

Information Sharing

• Internal database of 80,000 primary failures

• Project in place to develop an industry wide failure database with data from various utilities
Diminishing Expert Pool

• Internal and external
• Rebuild expertise internally
• Expand collaboration
• Attract new engineers
• Continue to improve the safety, reliability, and performance of electric distribution by expanding the knowledge of existing cable systems and developing applications for new technologies
Cable and Splice Center for Excellence

• 11,000+ sq-ft test facility
• Failure analysis center
• Diagnostic test lab
• High voltage test center
• Member of the EPRI Cable Testing Network (ECTN)
Cable and Splice Center for Excellence

- HV Test Areas
- Cable Prep. Area
- Diagnostic Area
- Failure Analysis Area
- Conduit & Manhole System
- Office Area
EPRI is a non-profit organization, funded through its members, that facilitates the research and development efforts of electric utilities
The EPRI Cable Testing Network is a platform for collaborative research and technology application to better assess the condition of cable systems and more reliably operate those parts of the electric delivery system.
Cable and Splice Center for Excellence

• Failure Analysis
  • 1,800 – 2,000 primary failures annually

• Diagnostic Testing
  • Metallographic
  • Chemical
  • Moisture

• Electrical Testing
  • 400 kV impulse
  • 120 kV AC
  • 180 kV DC
  • 2000 A High Current
Failure Analysis on Secondary System Components

• Associated with Stray Voltage and Manhole Events

• Secondary Mains
• Secondary Services
• Splices (crab joints, 2w-1w)
• Street Light Services
• 300+ analyses performed
### Causes of Stray-Voltage from Cable Autopsies

**All Structures and Reporting Sources**

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<tr>
<th>CAJAC Failure Code</th>
<th>Failure Cause</th>
<th>Streetlights Failure Count</th>
<th>Streetlights Average Age</th>
<th>Con Edison Failure Count</th>
<th>Con Edison Average Age</th>
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<td>26</td>
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<td>32</td>
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<tr>
<td>70</td>
<td>Wear at the Duct Edge</td>
<td>5</td>
<td>43</td>
<td>2</td>
<td>84</td>
</tr>
<tr>
<td>131</td>
<td>Defective Repair</td>
<td>1</td>
<td>74</td>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td>69</td>
<td>Rodent Bites</td>
<td>0</td>
<td></td>
<td>2</td>
<td>49</td>
</tr>
<tr>
<td>62</td>
<td>Mechanical Damage</td>
<td>0</td>
<td></td>
<td>2</td>
<td>39</td>
</tr>
<tr>
<td>74</td>
<td>Sheath Fatigue</td>
<td>0</td>
<td></td>
<td>1</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>3</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td></td>
<td><strong>61</strong></td>
<td><strong>45 Years</strong></td>
<td><strong>34</strong></td>
<td><strong>44 Years</strong></td>
</tr>
</tbody>
</table>
Integrity Testing on Secondary Components

• Test effect of “pricks” on insulation
  • EPR
  • Neoprene
• Hydrostatic Test
• Electrical Test
• Results
  • EPR recovers quickly after “pick”
  • Rubber neoprene less resilient than EPR
  • Neither insulation “leaked” current
• Sidewalk Test Setup
• Two steel conduits & service boxes
• Map Stray Voltage Profile
Stray Voltage Testing

Stray-Voltage On Concrete Surface Due To Energized Conduit

![Graph showing voltage levels applied to conduit and measured from concrete surface with different surface conditions (dry and wet)].
Stray Voltage Testing

Stray-Voltage On Concrete Surface Due To Energized Conduit

System B Saline solution and Rock Salt

Grid Positions

Grid Position Letters

A B C D E F G H I J K 0 2 4 6 8 10 12 14 16

Voltage Range

- 22.5-23
- 22-22.5
- 21.5-22
- 21-21.5
- 20.5-21
- 20-20.5
- 19.5-20
- 19-19.5
- 18.5-19

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