EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Project Set 128 B

Stray Voltage Analysis Tools & Technologies

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128.004 – Elevated Neutral-to-Earth Voltages and Urban Stray Voltage Concerns in Distribution Systems

- **Project 2007-2009 Objectives**
  - Continue to fill in the *remaining gaps* in the stray and contact voltage related research roadmap in order to more accurately quantify and remediate contact voltage concerns
- **What are those remaining gaps?**
  - Measurement (diagnostics)
  - Mitigation
  - Proposed limits and 'levels of concern'
  - NEV Baselines
- Different Application Areas – Rural, Urban and Residential

128.004 – Elevated Neutral-to-Earth Voltages and Urban Stray Voltage Concerns in Distribution Systems

- **2007 Work with Continuation in 2008 +**
  - Evaluate selected measurement equipment or mitigation devices to support a comprehensive NEV and Urban Stray Voltage Investigators Toolbox 
  - Via the EPRI contact voltage website - Provide comprehensive and technically accurate materials to support investigations and understanding of mitigation options 
  - Support ongoing IEEE “contact voltage” standards efforts and other industry and association efforts 
  - Provide credible data on typical NEV levels for feeders and circuits to better define regulator expectations regarding grounded neutral circuits 

Evaluation of Measurement and Mitigation Equipment

- Credible assessment of diagnostic equipment and mitigation devices serves to support a more comprehensive NEV and Urban Stray Voltage Investigators Toolbox
  - Examples:
    - Lenox and Knoxville test facilities
    - Clarksville, TN swimming pool
    - Erwin TN, gas pipeline
    - Pensacola, FL boat lift
- Primary focus areas are:
  - Mitigation Techniques
  - Existing Measurement Devices
  - Developmental Measurement Device Needs

Testing to be accomplished in controlled laboratory setting or at field locations depending on the device

Examples of the Field Locations

Evaluate Measurement and Mitigation Equipment
Focus Area 1 – Mitigation Techniques – Ground Ring

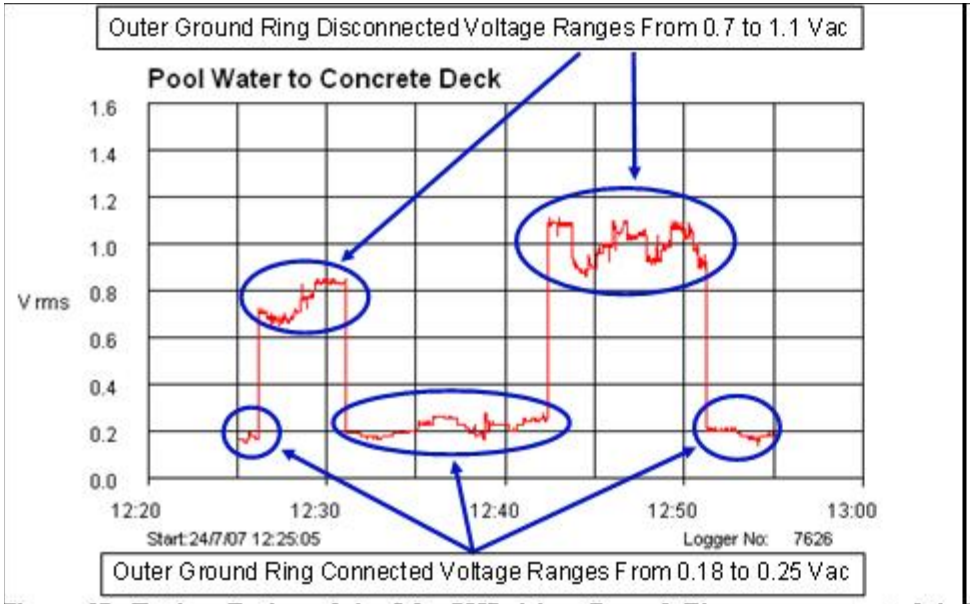


Figure 13, Testing Performed in July 2007 After Ground Ring was compacted in Surrounding Earth.

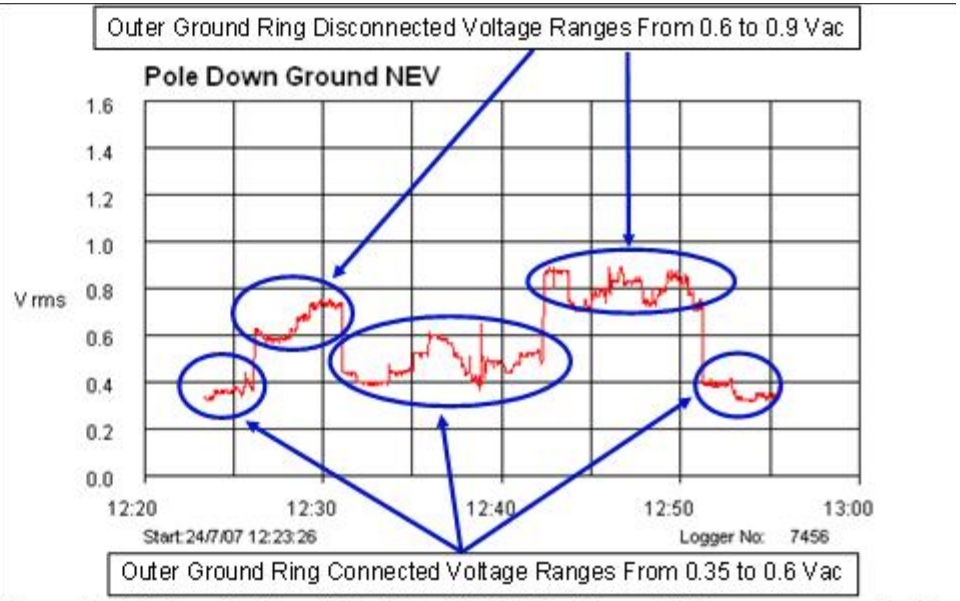
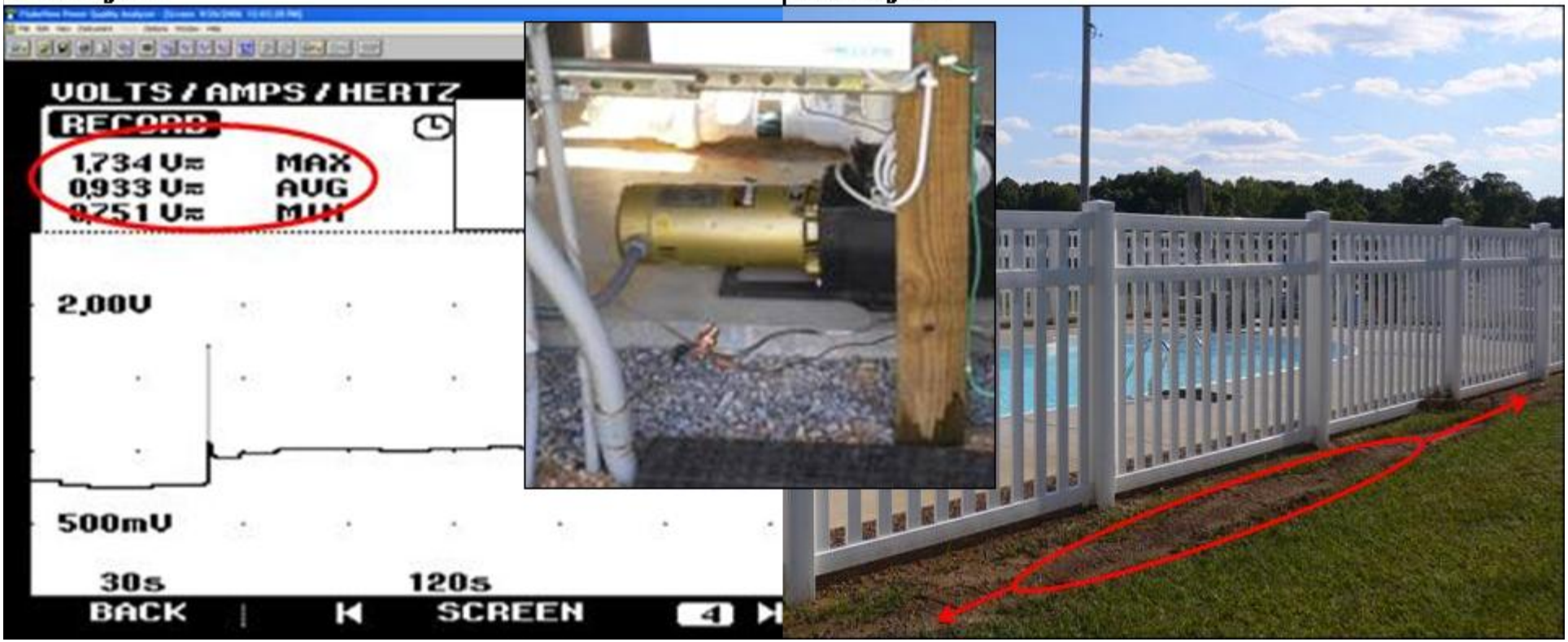
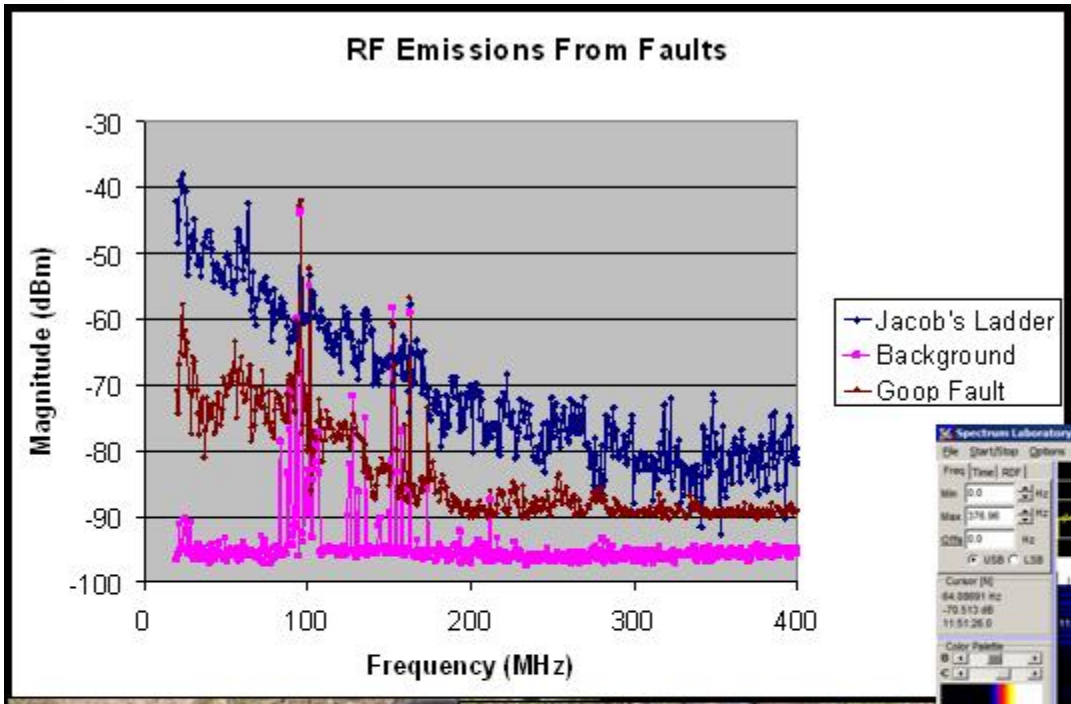


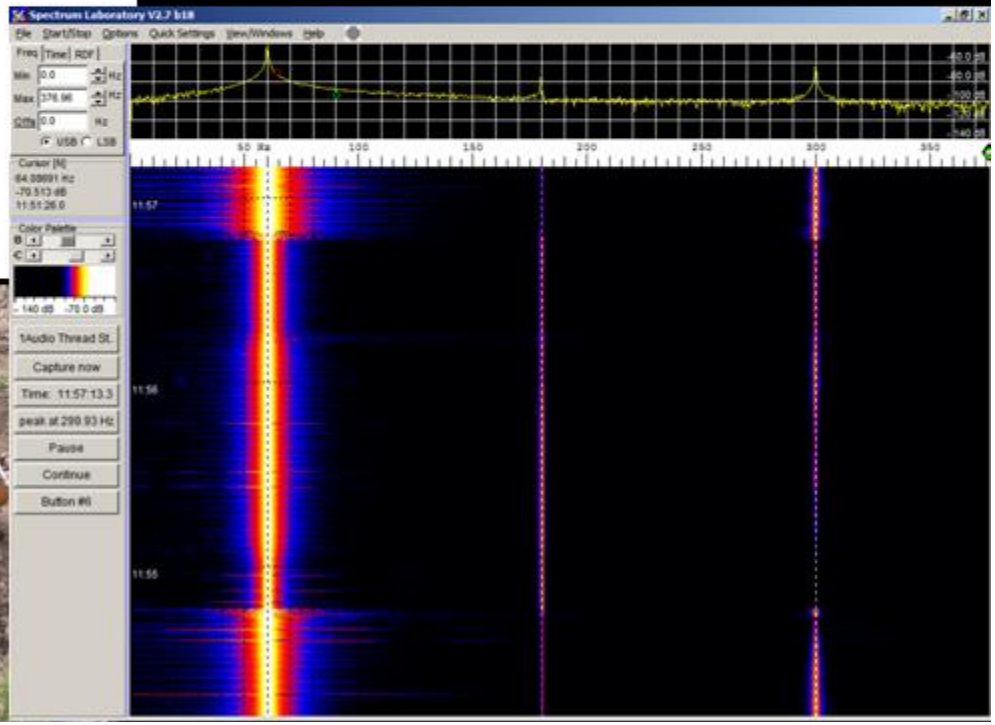
Figure 14, Testing Performed in July 2007 After Ground Ring was compacted in Surrounding Earth.



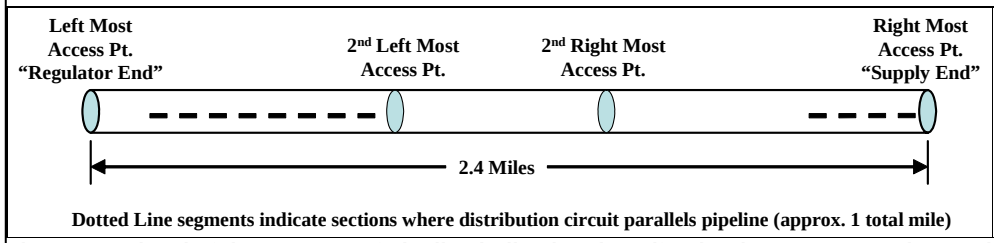
Evaluate Measurement and Mitigation Equipment
Focus Area 3 – Developmental Measurement Devices



- Testing covered frequency range from 60Hz to 400 MHz
- 10 different test and measurement devices were evaluated
- Data analysis will be completed in July



Focus Area 3 – Developmental Measurement Devices - Easier Identification of the Contact Voltage Source



Dotted Line segments indicate sections where distribution circuit parallels pipeline (approx. 1 total mile)

Figure 1-A Visual of the segment of pipeline indicating the 4 (four) voltage access points and the parallel distribution line locations.

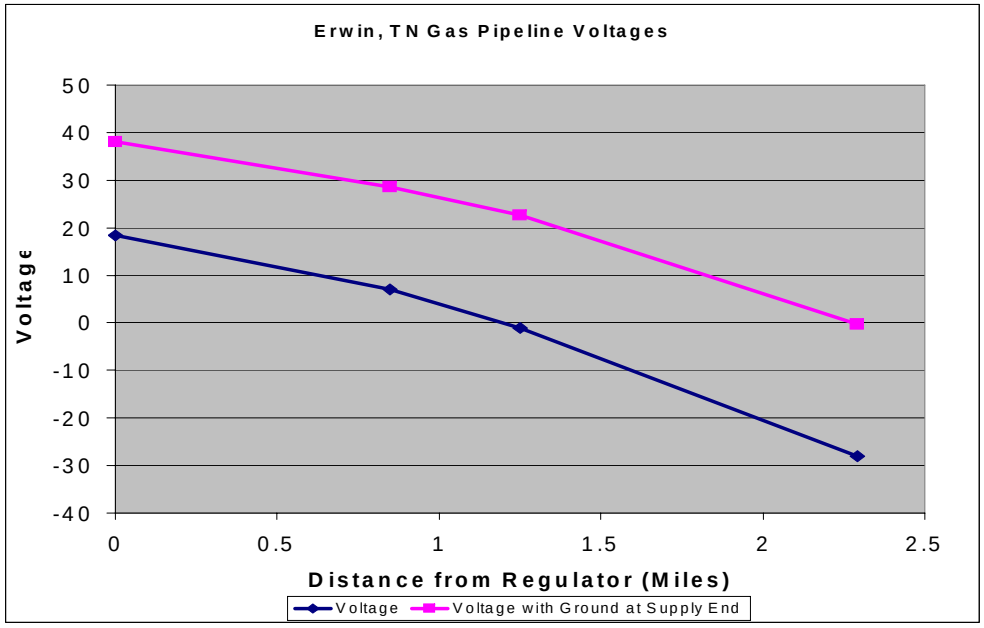


Figure 1B. Voltage Plots with Supply End (Right side of Graph) of Pipe Segment "Grounded" and "Ungrounded" (the negative voltage indicates that end of the pipe it is "out of phase" with respect to the other end of the pipe segment). Left side of graph is the end of the insulated pipe segment where the pressure regulator is located.

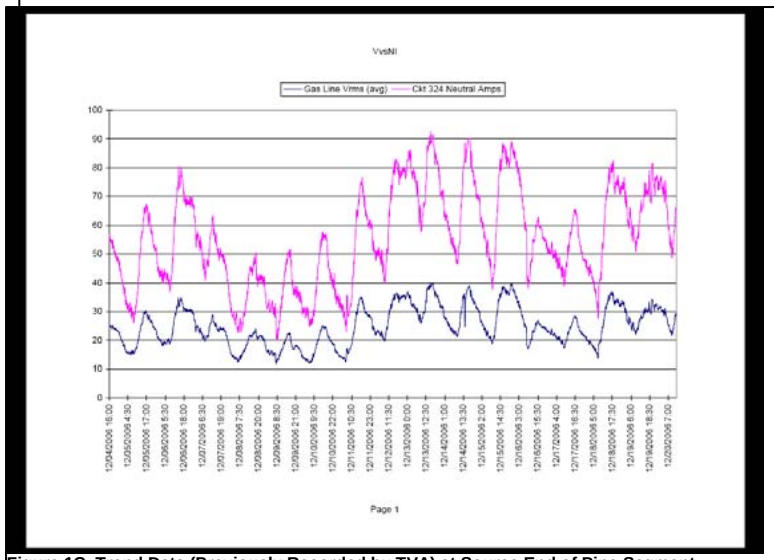
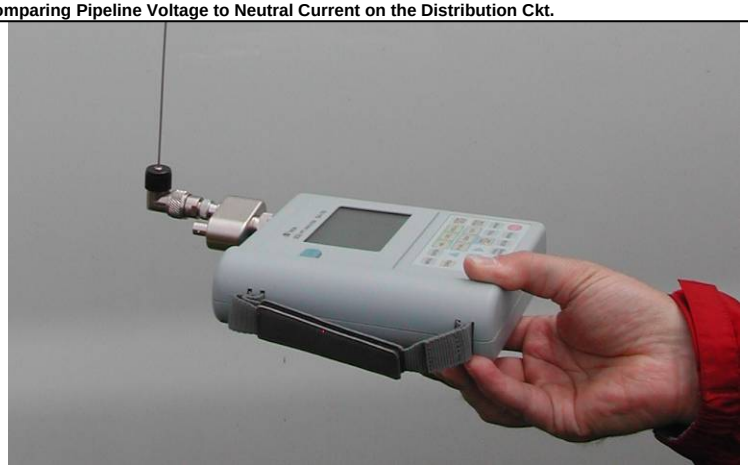


Figure 1C. Trend Data (Previously Recorded by TVA) at Source End of Pipe Segment Comparing Pipeline Voltage to Neutral Current on the Distribution Ckt.



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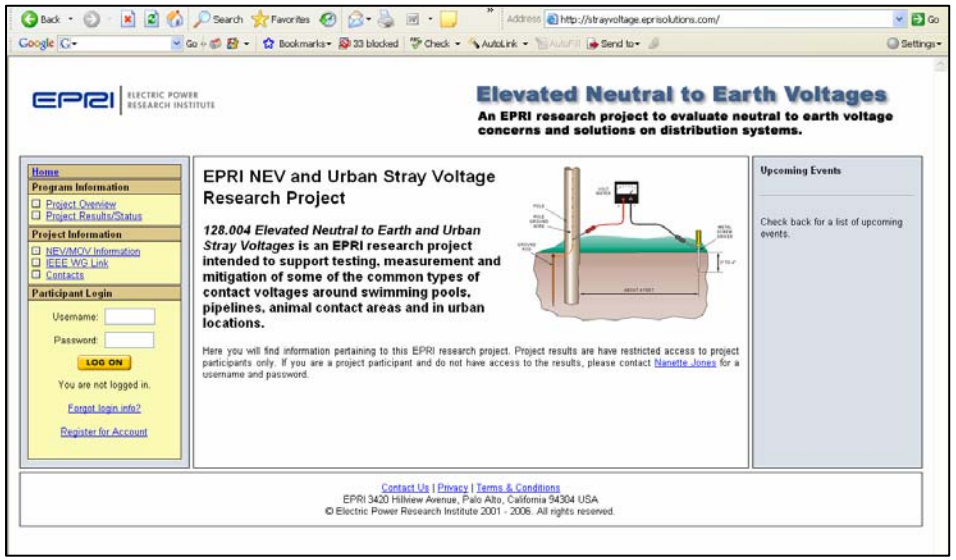
Objective: Credible and Technically Accurate Materials for the EPRI Contact Voltage Website

- Website
  - Update existing information to reflect 2007+ level of understanding
  - Materials should support investigations and understanding of mitigation options
  - Provide more application guidance on use of test and measurement equipment
  - Provide more application guidance on mitigation solutions



- Vision Statement
  - The EPRI ‘Contact Voltage’ website is the preferred resource for credible and unbiased understanding of the evaluation and mitigation of contact voltage related concerns

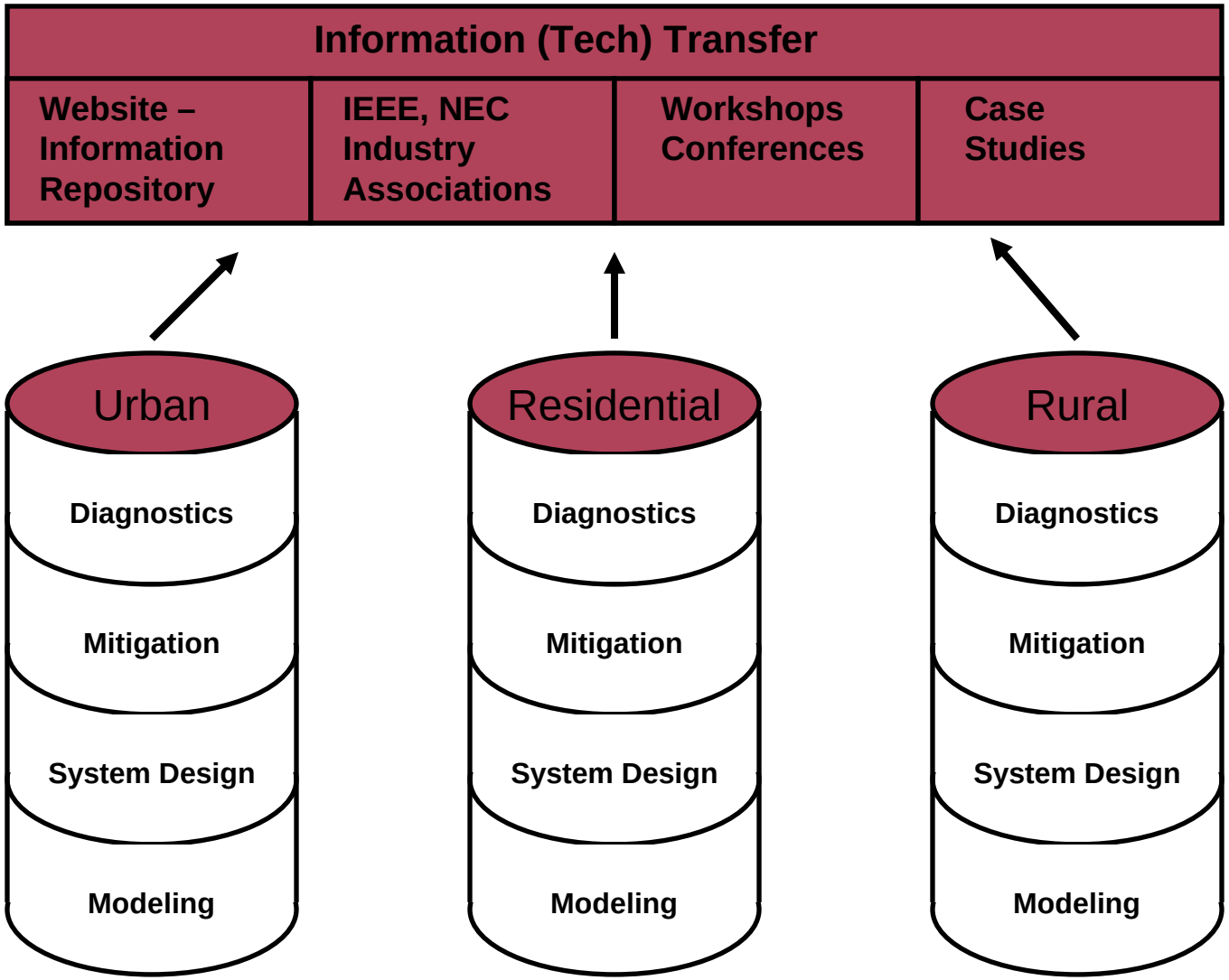
- **http://www.strayvoltage.eprisolutions.com**

2008+ Objective: Support ongoing IEEE 'Contact Voltage' Standards Efforts – 'General Intent'

- Facilitate 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, multi-grounded neutrals, and high impedance power system and load faults
  - Standardized measurement protocols and procedures
  - Proposed voltage levels of concern for various situations

Reference Document	Published Level	Concern Category
UL-101	0.75 milliamps (hardwired with ground conductor) 2000 ohm human body impedance model	Reaction Current
UL 60950-1	42.4 Vac or 60 Vdc is the stated limit under dry conditions and human hand path	Shock Hazard
IEC 479-1	25Vac clearly safe, 50Vac marginally safe depending on duration	Shock Hazard
OSHA Rule" (29 CFR Part 1910) 2004	Circuits operating above 50 Vac or 50 Vdc	Shock Hazard
NFPA 70E	30 Vrms or 60 Vdc 500 ohm wet human body resistance	Shock Hazard
IEEE Yellow Book – Std. 902-1998	Currents as low as a few (10) milliamps and Voltages above 50V can cause fibrillation 500 ohm minimum body resistance for wet conditions or cuts and abrasions	Heart Fibrillation
NACE	15 Volts	Shock Hazard
NESC	51 Volts	Shock Hazard
NEC	Circuits operating above 50 Vac or 50 Vdc 15 V for wet areas	Shock Hazard
IEEE Std 80	60 Vac for 4 sec	Shock Hazard

Contact Voltage (Stray Voltage) Research Opportunities



Con Ed Funded Early Detection Research

- EPRI and Consolidated Edison technical staff have identified several opportunities to expand on the ability to perform early detection of urban stray voltage. This resulted in preliminary concept development and subsequent feasibility testing – performed in June 2007, at the EPRI Knoxville and EPRI Lenox test facilities
- EPRI then proposed (and Con Ed is funding) a follow-on research project targeted at developing algorithms and instrumentation that will advance the state-of-the-art in early detection of urban contact voltage situations
- The first objective the research effort is to develop suitable hardware and analytical tools intended to first, advance the state-of-the-art in detecting pre-cursor events that ultimately result in an inadvertent energization concern
- The second objective is to provide directional capabilities for detection of energized objects where overhead power lines may interfere with existing early detection methods

Project Opportunity - Swimming Pool Bonding

Draft - project opportunity - Draft

EPRI

Evaluation of Bonding and Grounding Around Swimming Pools

Just a few volts at a wet contact location such as a swimming pool or spa can create perception and corresponding complaints from customers. The most prevalent concerns occur when the pool or spa is constructed without the NEC® article 680 required equipotential plane beneath the decking material surrounding the swim area.

BACKGROUND

Many nuisance shocking and tingling complaints around swimming pools and spas are the result of elevated neutral to earth voltage potentials that become even more pronounced when the grounding and bonding around the complaint location are inadequate.

The most prevalent concerns occur when the pool or spa is constructed without the NEC® article 680 required equipotential plane beneath the decking material surrounding the swim area.

PROJECT SUMMARY

This project will provide sponsors with an opportunity to replicate pool and spa contact voltage scenarios in a controlled environment at EPRI's Lenox, MA test facility. Instead of relying on field measurements at locations where the background conditions cannot be easily varied – the test pool – constructed specifically for this project – will be designed with the flexibility to vary any parameter that can create nuisance shocking concerns.

To accomplish the project objectives a residential size swimming pool will be installed at the test facility.

Project Opportunity - Swimming Pool Bonding

1 = Water to Metal Ladder – Vac = 0.00

2 = Metal Ladder to Cement Deck – Vac increases as X moves further away

3 = Metal Ladder to Cement Deck – Vac increases as X moves further away

4 = Water to Coping Stone – Vac = 0.00

5 = Water to Cement Deck at 1 ft – Vac fluctuates with primary neutral and house power draw and can exceed perception levels

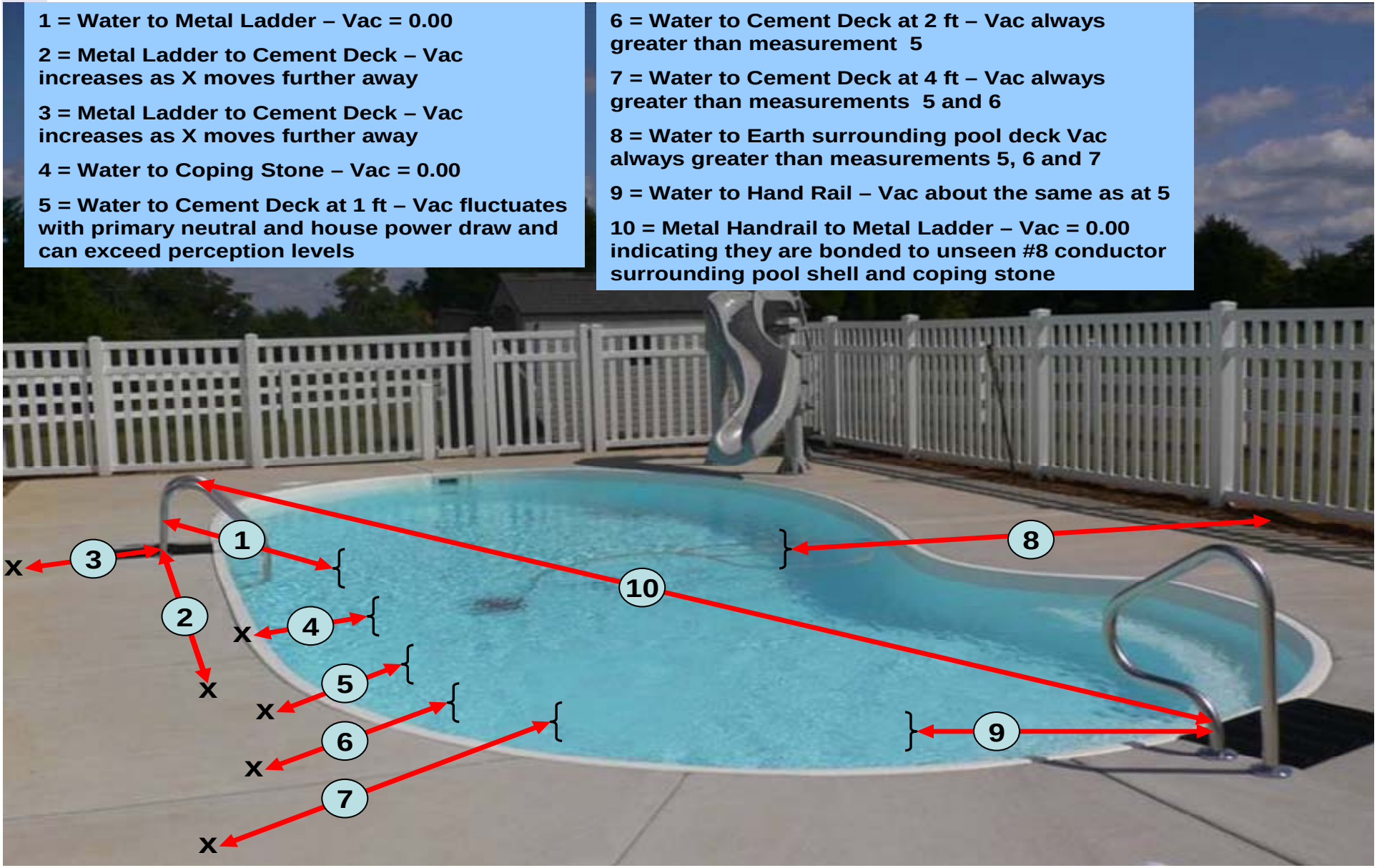
6 = Water to Cement Deck at 2 ft – Vac always greater than measurement 5

7 = Water to Cement Deck at 4 ft – Vac always greater than measurements 5 and 6

8 = Water to Earth surrounding pool deck Vac always greater than measurements 5, 6 and 7

9 = Water to Hand Rail – Vac about the same as at 5

10 = Metal Handrail to Metal Ladder – Vac = 0.00 indicating they are bonded to unseen #8 conductor surrounding pool shell and coping stone



Project Opportunity – Animal Contact

Draft - project opportunity

EPRI

Stray Voltage Effects on Dairy Cows – Meta Analysis

Numerous studies have been conducted to define dairy cow response to contact currents. Meta Analysis provides a means of objectively evaluating and combining the results of the various studies to come up with a credible and unbiased response threshold that may serve as the basis for future limits and levels of concern.

BACKGROUND

There are a range of opinions about the response threshold of a dairy cow with exposure to contact currents, due to "stray voltage conditions." Numerous studies have assessed the characteristics of exposure that cause dairy cows to respond to long-term and short-term exposure to these contact currents. The identification of a response threshold is the basis for regulatory actions that limit potential environmental exposures. These studies have been the basis of regulatory decisions to limit exposures of dairy cows (PSCW, 1996).

if they truly exist). Because smaller studies are combined, the sample size is increased and more precise results are obtained.

This research project will provide sponsors an opportunity to more accurately quantify dairy cow response thresholds to contact currents and associated "stray voltage levels."

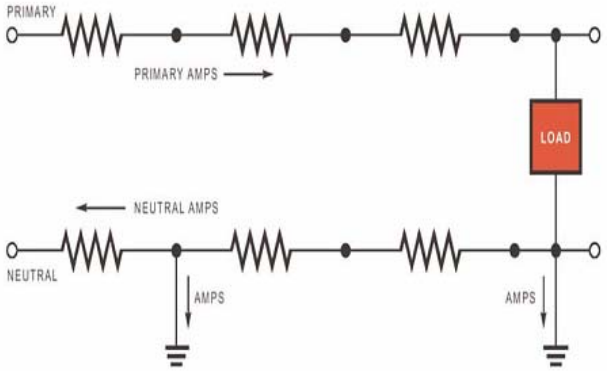
PROJECT SUMMARY

This project would enlist a select group of experts well versed in the subject matter of meta analysis and in animal physiology to perform the subject work. The

Project Opportunity – Under Performing Power System Connections and Hardware

Draft – EPRI Project Opportunity - Draft

Methods for Detecting High Impedance Conductors and Other Under Performing Power System Connections and Hardware



There are numerous ways to detect and locate under performing power system hardware, but most are very time consuming, and require a substantial time and resource investment.
New detection and location techniques can assist in both prioritization and speed of repair – while concurrently reducing the manpower investment.

BACKGROUND

There is an industry need to have better means of early detection of power system hardware in need of preventive maintenance.

One such area of opportunity involves the detection and location of broken, corroded and high impedance neutral conductors and associated connectors as this area can create stray voltage concerns for multiple customers on the same circuit.

efficient ways to identify and locate under performing or malfunctioning hardware and connection points.

PROJECT SUMMARY

This research effort will evaluate the existing techniques used for location of under performing power system hardware and will subsequently work with vendors of technologies that show promise in improving the efficiency of this process. One such technology that will be evaluated is the Exacter® system which shows promise in attaining the project objectives of faster detection and ability to provide