Elevated Neutral to Earth and Metallic Object to Earth Voltage Assessment Project

Doug Dorr

EPRI PEAC Corp

March 4th 2004

Webcast Presentation Protocol

- If you are having any technical problems during the webcast press *0 for help
- During the main presentation, your telephone connection will be valid for listen mode but your voice will not be heard by other attendees
- During the Q&A session you may ask questions by pressing *8 which will put you in the queue for questions. When the moderator adds you to the presenters list, you may ask your question
- Q&A will be limited to ½ hour, but all questions submitted will be answered via email

Presentation Summary

- Elevated NEV and MOEV definitions and description
- What causes elevated NEV (neutral to earth voltage)
- What causes MOEV (metallic object to earth voltage)
- How does NEV affected humans and animals
- Approaches to remedy elevated NEV concerns

Presentation Summary Cont.

- Why the need for a single information repository
  - Measurement protocols
  - Assessment of published levels of concern
  - Case Studies
  - Remediation techniques to minimize NEV levels
  - Document and website archive
- 2004 EPRI Elevated Neutral to Earth and Metallic Object to Earth TC Project
- 2005-2007 EPRI Base Research Initiatives
- Question and Answer Session

Elevated NEV Definitions and Description

- NEV – Neutral to Earth Voltage
  - The measured voltage value at the point of interconnection between the utility primary neutral conductor and a (zero reference) remote earth point typically a few hundred feet away from the point of interest
- MOEV – Metallic Object to Earth Voltage
  - The measured voltage value at the point of interconnection between the metallic object and a (zero reference) remote earth point typically a few hundred feet away from the point of interest
- Stray Voltage
  - A voltage (<10V) developed across any two points that can be contacted by an animal or by a person.
  - *Note that animals and humans are impacted by current levels and not by voltage*

What are Some of the Concerns Fielded by the EPRI PEAC PQ Hotline?

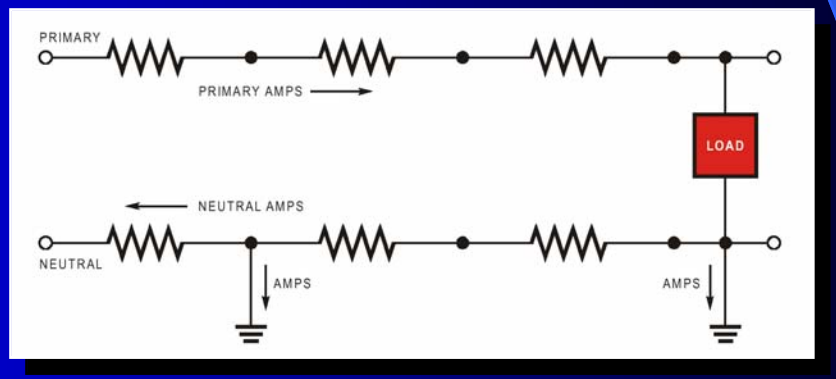
- Personnel safety concerns related to touch potentials
- Animal contact area concerns related to health and productivity impacts
- Residential water and gas pipe shocking concerns
- Harmonic frequency voltages imposed on industrial gas lines by non-linear loads
- Power circuit resonance conditions creating magnified stray voltage potentials
- Insulated Metallic pipe corrosion concerns
- Impacts of power line carrier communications technologies and other transient switching devices on stray voltage magnitudes
- Impacts of new gas and water line installations in power line right of ways
- Different opinions on measurement equipment specifications, measurement protocols and measurement durations

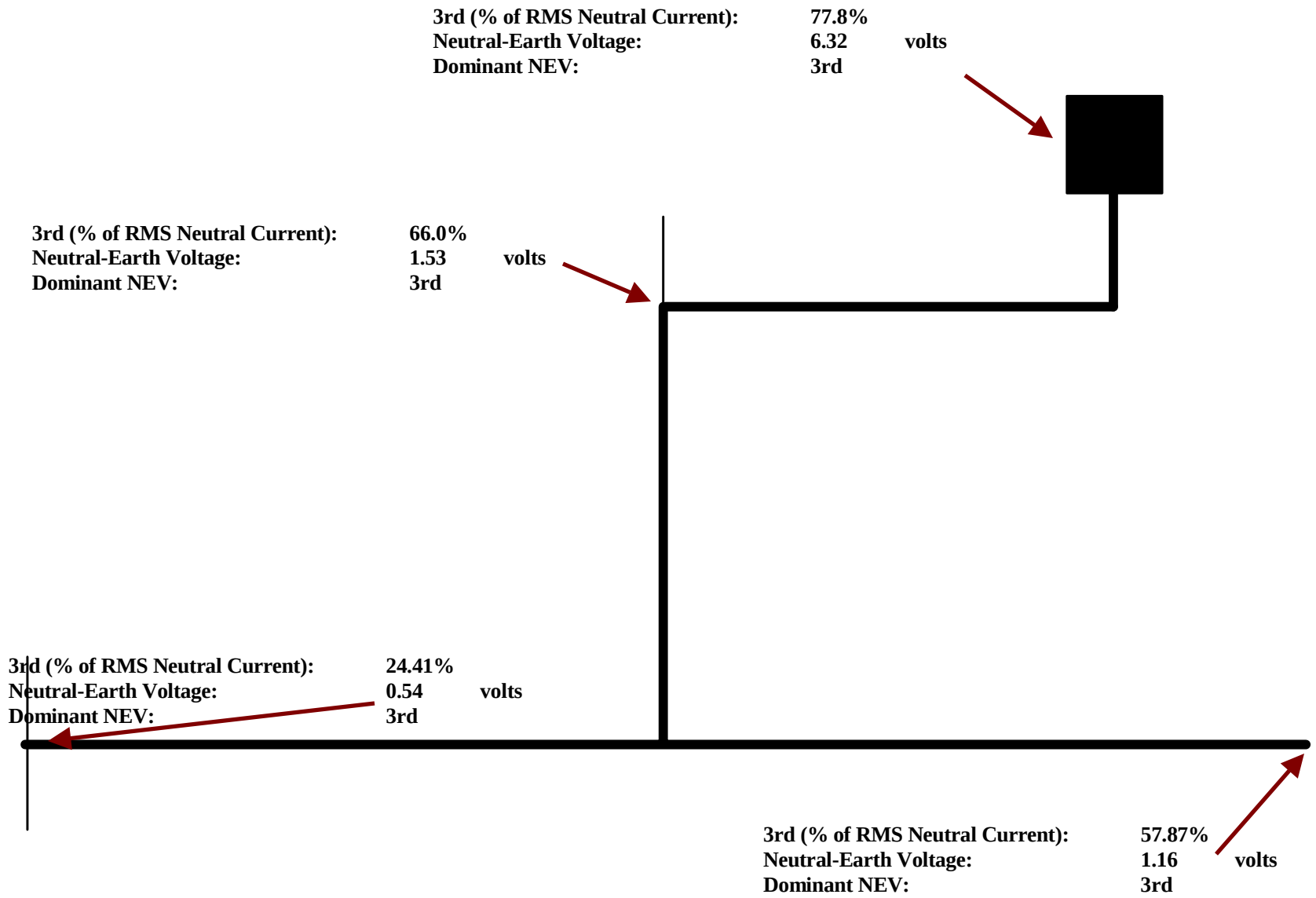
What Causes Elevated NEV and Elevated MOEV?

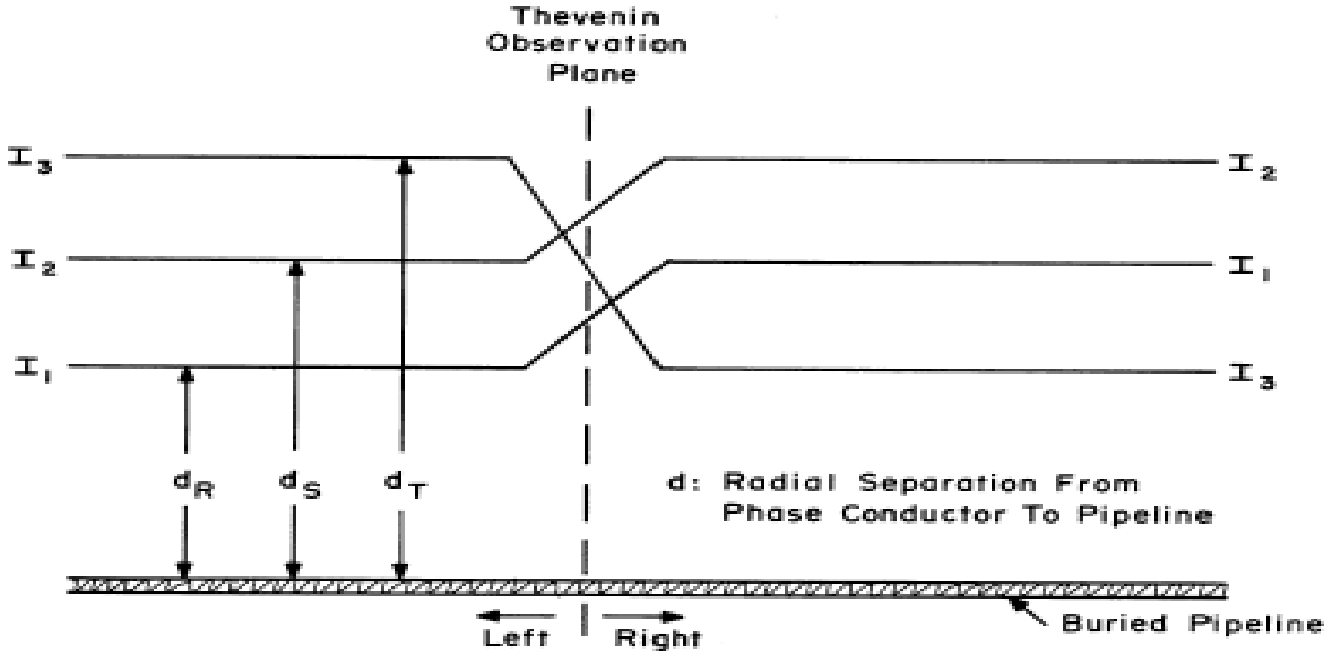
- Primary Utility Distribution Circuit Neutral Currents
  - Results in a voltage between remote earth and the primary reference point
- Unbalanced three phase circuit loading results in less neutral current cancellation
- Equipment faults supply unexpected voltage sources at contact locations
- High impedance connections result in higher levels of voltage at contact locations
- Improper wiring can contribute to undesirable voltage sources at contact locations
- Magnetic Coupling from transmission and distribution lines onto insulated pipelines creates undesirable touch potentials

High Impedance Neutral

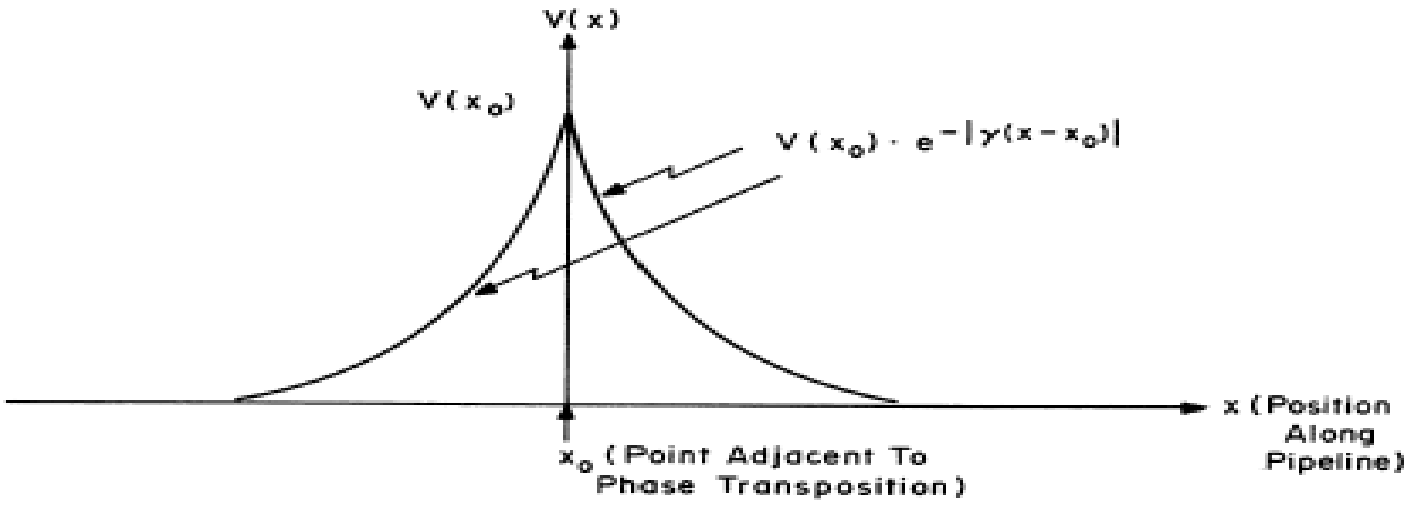
- A high impedance neutral path causes excessive voltage drop on the neutral, which will appear as a potential difference between the neutral/grounding system and the earth.
- Any metal objects bonded to the system neutral will be at a higher potential than the surrounding earth.




3rd (% of RMS Neutral Current): 77.8%
Neutral-Earth Voltage: 6.32 volts
Dominant NEV: 3rd
3rd (% of RMS Neutral Current): 66.0%
Neutral-Earth Voltage: 1.53 volts
Dominant NEV: 3rd
3rd (% of RMS Neutral Current): 24.41%
Neutral-Earth Voltage: 0.54 volts
Dominant NEV: 3rd
3rd (% of RMS Neutral Current): 57.87%
Neutral-Earth Voltage: 1.16 volts
Dominant NEV: 3rd



a) Phase Transposition Configuration



b) Induced Pipeline Potential

How Does Voltage Touch Potential Affect Humans and Animals?

- The impact on humans and animals is a function of the contact voltage, the impedance of the voltage source, and body impedance
- Actual reaction and perception thresholds are based on the current flow through the body and can be different for AC and DC waveshapes
- 0.5 to 2 milliamps is the perception threshold for humans while 6 to 23 milliamps is the limit at which it is hard to "let go" of a live conductor
- 100-500 ohms is a typical resistance range for feet or hands immersed in water, while 500 – 3000 ohms is typical for a hand around a metallic water pipe under wet conditions

How Does Voltage Touch Potential Affect Humans and Animals?

- University of Wisconsin testing indicated that 3-20 milliamps “peak current” was the range for over 200 dairy cows tested in 1999 “Reinemann et. al.”
- Useful References
  - EPRI TR 114340 “Stray Voltage Sensitivity Levels for Dairy, Swine and Poultry”
  - EPRI TR 113566 Identifying Diagnosing and Resolving Residential Shocking Concerns
  - EPRI EL-3106 V1, V2, V3, V4 This report series addresses complex common corridor coupling problems for overhead electric power transmission lines and buried natural gas pipelines

Approaches to Remedy Elevated NEV Concerns

- Approaches differ depending on the cause of the elevated NEV
- It is highly important to determine the cause of the elevated NEV and whether or not there is any adverse impact before evaluating mitigation options
- For example, decreasing neutral conductor impedance will not help if the cause of the elevated NEV measurement is a load fault or a facility wiring problem

Approaches to Remedy Elevated NEV Concerns

- Increase neutral conductor sizing
- Reduced Substation ground resistance
- Improved pole ground resistance
- Better load balance
- Capacitor bank configuration optimization
- Improved grounding at contact points

Approaches to Remedy Elevated NEV Concerns

- Isolating secondary neutral conductors
- Customized mitigation hardware
  - Transformers
  - Surge protective devices

Examples

- AMR Results
- Higher Voltage Distribution
- Harmonic Filters

The Need For a Single Information Repository

- Measurement protocols
- Assessment of published levels of concern
- Case Studies
- Remediation techniques to minimize NEV levels
- Document and website archive

Measurement Protocols

- Consistent and repeatable measurements can be very difficult to obtain when considering the dynamic variations related to NEV levels
  - Ground resistances change with season and moisture levels
  - “Remote Earth” reference point can have a significant impact on the measured NEV
  - Circuit loading will impact NEV levels, therefore significant differences may be observed in distribution circuit measurements not taken at the same time
  - Triplen harmonic currents add in a neutral conductor therefore measurement protocols need to define ways to assess the harmonic currents and their phase angles

Assessment of Published Levels of Concern

- Presently, a number of states are monitoring elevated NEV concerns and are looking to develop guidelines and “levels of concern” above which remedial actions should be taken. “This includes human touch levels”
- EPRI is in a position to bring a North American as well as an International perspective to this effort to support an informed decision making process

Website and Document Archive

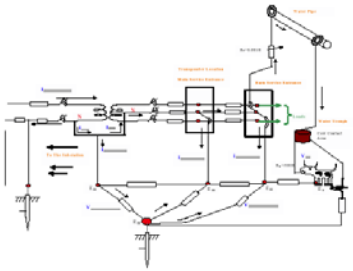
- The website is presently in progress with a number of areas already populated
- http://strayvoltage.epri-peac.com/

2004 EPRI Elevated NEV Project

project opportunity

EPRI

Identify Stray and Neutral to Earth Voltage Impacts and Controls



There are numerous concerns related to stray voltage, but no systematic means to measure the actual impacts or implications of stray voltages. This research aims to deliver consistent, repeatable stray voltage measurement, assessment and mitigation methodologies.

BACKGROUND Elevated neutral to earth voltage (NEV) and metallic object to earth voltage has long been an area of concern and subjective interpretation for utilities, regulators, and the public. Sources range from induction of voltage onto metallic infrastructure (such as conduits, water pipes, and gas pipes) to unanticipated current paths created by grounding configurations and connection impedances. While steady state 60Hz stray voltage and elevated NEV issues have been a long standing concern, the increasing use of non-linear (or harmonics generating) electronic equipment—such as variable speed drives, personal computers, and residential appliances—are continually adding to these elevated voltage potentials. Additionally, the impact of momentary or transient neutral to earth voltage has become a more recent topic of study.

There is an industry need to establish measurement protocols, to better understand the coupling issues related to stray voltages, and to identify cost effective solutions.

There are numerous stray and elevated voltage concerns, including:

- Safety concerns related to touch potential
- Animal health and productivity
- Current carried on residential water and gas pipe lines
- Harmonic frequency voltages imposed on industrial gas lines by non-linear loads
- Power circuit resonance conditions creating magnified stray voltage potentials
- Metallic pipe corrosion concerns
- Impacts of power line carrier communications technologies and other transient switching devices on stray voltage magnitudes
- Impacts of new gas and water line installations in power line right of ways

While research has been conducted in most of these areas, there is a lack of consistency in terms of quantifying the impacts, and whether or not a specific measured value is at or below a specified "level of concern."

This research project will provide electric utilities and regulatory organizations with an opportunity to better understand the range of issues surrounding the subject of measurable voltage levels at human and animal contact locations and to benefit from some unbiased and credible research geared toward developing acceptable methods to evaluate and address elevated voltage concerns.

PROJECT SUMMARY This project is designed to assess the important concerns associated with elevated neutral to earth and metallic object to earth voltages at human and at animal contact points by promoting consistent and repeatable assessment methodologies, hosting workshops, and creating a "case study" and "general information" repository. These and other project efforts shall be geared toward expediting problem identification and resolution.

Power Delivery and Markets Sector *September 2003*

2004 EPRI Elevated NEV Project

- Evaluation of Impacts and Mitigation Techniques for Neutral to Earth and Stray Voltage Sources
- An EPRI sponsored initiative to facilitate better understanding of the issues surrounding elevated voltage related measurement techniques, acceptable levels, and reduction methods
- This project will not duplicate any previous effort but will aggregate prior results, supplement the information where required and move forward in terms of requirements to advance the state of the art in understanding of the elevated NEV topic

2004 Elevated NEV Project

- Proposed Deliverables Include:
  - Custom Modeling and Simulation Services
  - International Regulatory Assessment
  - Website aggregating all relevant materials by subject (including case studies)
  - Recommended Practices Documents
  - Informational and Support Hotline

2004 Elevated NEV Project

- Sponsor Benefits
  - Participation in this project brings to your staff a team of experts to support assessments and remedial measures related to Elevated NEV and MOEV potentials
  - Additionally independent third party validation of measurements and implementations can be obtained

2005 - 2009 EPRI Base Project

- Follow-on efforts to the 2004 work
  - Results will start to become available 1st quarter 2006
  - Characteristics of customer loads and circuit configurations that contribute to neutral-to-earth voltages will be described. The affect of different distribution system characteristics will also be addressed. Solutions for neutral-to-earth problems. Through case studies and simulations, example solutions for a wide variety of different neutral-to-earth voltage concerns are developed. These include traditional solutions and new approaches
  - Harmonic voltage concerns will be factored in

2005 - 2007 EPRI Base Project Cont.

- All participants will receive access to the application guide that is created as part of a collaborative research project. The application guide will provide the initial foundation for an ongoing effort to identity and control elevated NEV *"In all areas of interest"*
- Project will include updated information on evolving regulatory and legal issues, particular problems being experienced, models for neutral-to-earth evaluations, and solution techniques.
- Expanded case studies will provide the basis of a library on neutral-to-earth issues. This will be provided as an on-line resource for members

Summary

- The initiatives surrounding the “Elevated Neutral to Earth and Metallic Object to Earth Impacts and Controls” project are intended to supplement “not repeat” any previous or ongoing efforts
- The information repository and informational hotline are intended to bring major support and technical expertise to personnel investigating elevated voltage concerns

For More Information Contact

- Doug Dorr ddorr@epri-peac.com
- Mark McGranaghan mmcgranaghan@epri-peac.com
- Arindam Maitra amaitra@epri-peac.com

- Ashok Sundaram asundara@epri.com
- Askepri@epri.com

Questions and Answers

- Format: Press *8 on your telephone keypad to be placed in the queue for a question…. When you get to the top of the queue you will be placed into the general discussion group
- Since we expect over 80 call participants, other participant comments on the question will have to be moderated via the discussion box in the web browser and will be aggregated after the telecon