Standardized Measurements for Elevated NEV and Energized Object Concerns

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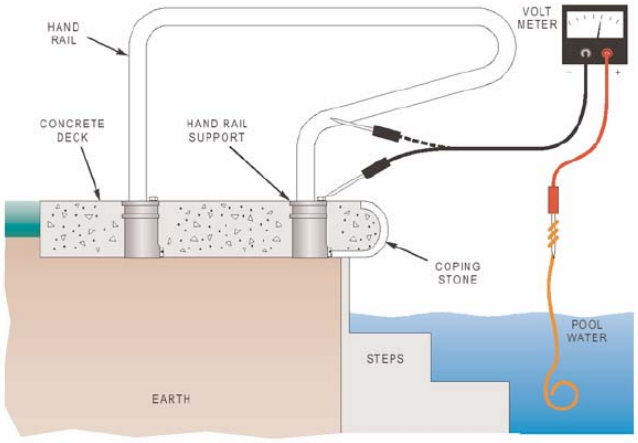
June 7th 2006



Presentation Summary

- Brief overview of past and present EPRI experiences related to contact voltages
- Observations related to measurement of contact voltages
- A case study involving both:
  - An energized gas pipeline
  - A neutral to earth voltage source
  - Improper bonding and grounding
- Discussion on the need for an IEEE guide that focuses at least “in part” on standardized measurement protocols
- Some suggestions on future IEEE related work

The TVA System

- 17,000 miles of transmission
- 11 fossil plants
- 29 hydroelectric dams
- 6 combustion turbines
- 1 pumped storage facility
- Serving 8.5 million residents in 80,000 square miles

A Selection of "Contact Voltage" Related Questions and Concerns - EPRI Solutions PQ Hotline 1994-2006

- Personnel safety concerns related to **touch potentials** – Gas pipeline trenches
- Animal **contact area** concerns related to health and productivity impacts
- Residential outdoor water faucet **shocking concerns**
- Harmonic frequency **contact voltages** imposed on industrial gas lines
- Power circuit resonance conditions creating elevated NEV levels
- **Tingling sensation** felt at a boat dock when dangling feet in water
- Questions about the impacts of power line carrier signals and other transient generating devices at animal **contact locations**
- Impacts of new gas and water line installations in power line right of ways
- Induced voltages causing **shocking sensations** from fences and light poles
- **Tingling sensations** when exiting swimming pools
- Different opinions on measurement equipment specifications, **measurement protocols** and measurement durations
- **Shocking sensation** felt when **contacting** a residential metal door frame
- Same level of voltage causing **shocking complaints** at one swimming pool, but not at a similar pool in a neighborhood served by the same power source

Observations Related to the Hotline Questions

- The source or “cause” of the concern is not always the same
  - Intentionally grounded neutral conductors creating neutral to earth voltages (NEV)
  - Unintentionally induced voltages from current flowing in power conductors (magnetic coupling)
  - Faulted power conductors unintentionally energizing other objects
  - Faulty customer wiring unintentionally using Kirchoff’s Current Law (KCL) to return to currents their source
  - Intentional and unintentional bonding issues at human and animal contact locations

More Observations Related to the Hotline Questions

- The complaint is the same but the concern is not!
  - The **complaint** is almost always **contact** related:
    a) A human or animal simultaneously **contacting** two points (at different voltage potential) and creating the path for current to flow between those two points
    b) A measurement taken that could result in a potential **contact** complaint
  - The **concern** is either:
    a) A **nuisance concern** from a shocking or tingling sensation where current flows are relatively small and typically result in changes in behavioral patterns or in sensitivity to the sensation (can be dealt with over weeks or months)
    b) A human and animal **safety concern** where current flows may exceed published levels of concern (need to be remediated as soon as the source can be identified and acceptable mitigation options defined)

EPRI Stray Voltage (Contact Voltage) Research Roadmap

- The prioritized research plan identified five areas of opportunity where supplemental or new research was needed:
  1. **Test and measurement protocols**
  2. Modeling and simulation guidelines
  3. **Test equipment and mitigation methods**
  4. Technology transfer - Informational website
  5. Regulatory guidance (NEV and MOEV baselines and what voltage levels are not a concern)
- **Areas 1 and 3 are the immediate concerns to TVA**

Generic Contact Voltage Evaluation Priorities

- Adequate call handling and response procedures
- Safe and accurate measurement protocols
- Adequate instrumentation and personnel training
- Consistent documentation for reporting and analysis
- Understanding of all the possible causes
- A procedure for “peeling the onion” start with all possibilities and systematically narrowing down the list
- Preventive maintenance and spot monitoring
- Design guidelines

Case Study – Contact Voltages on Gas Pipelines at a Central Tennessee Industrial Park

- Background
  - Complaints related to voltages on gas pipelines in an industrial park had been received by the serving utility on different occasions over a period of 8 years
  - Sometimes the presence of voltages were confirmed when the complaints were investigated, other times no voltages were measured at the complaint location
  - TVA requested support from EPRI Solutions to utilize newly developed measurement and evaluation protocols to assist in determining the cause(s) of the contact voltages

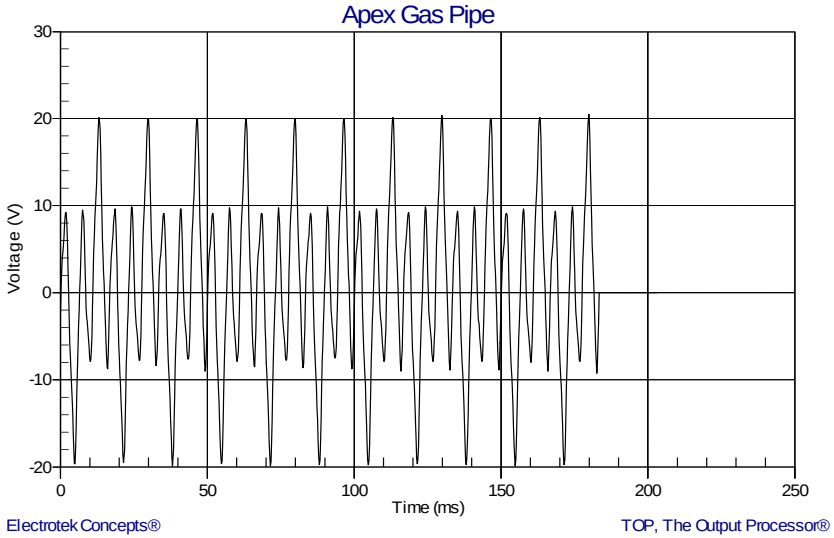
Case Study – Plan of Action

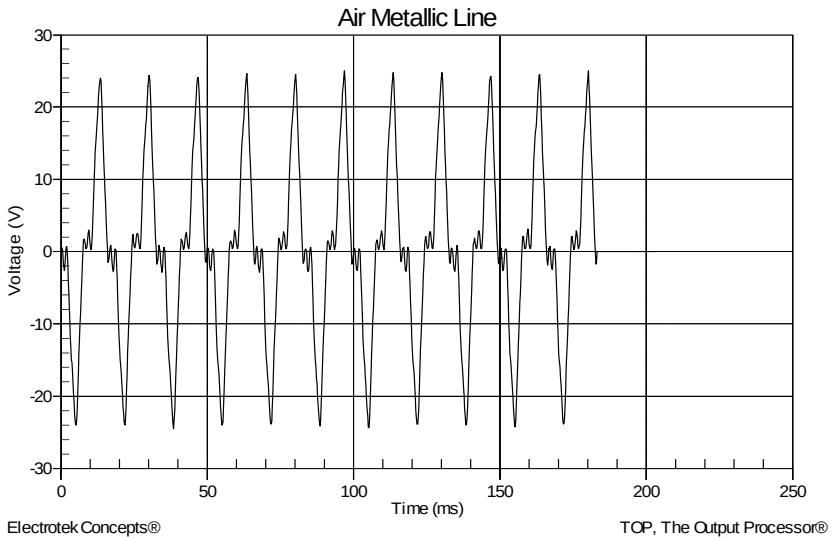
- Step by Step approach
  - Teleconference with all involved parties to define follow-on actions and responsibilities
  - Information gathering and follow-on teleconference to:
    - Answer outstanding questions
    - Define a plan of action
    - Determine the measurement equipment requirements
  - Schedule coordination with all involved parties to:
    - Insure equipment availability
    - Obtain access to measurement locations of interest

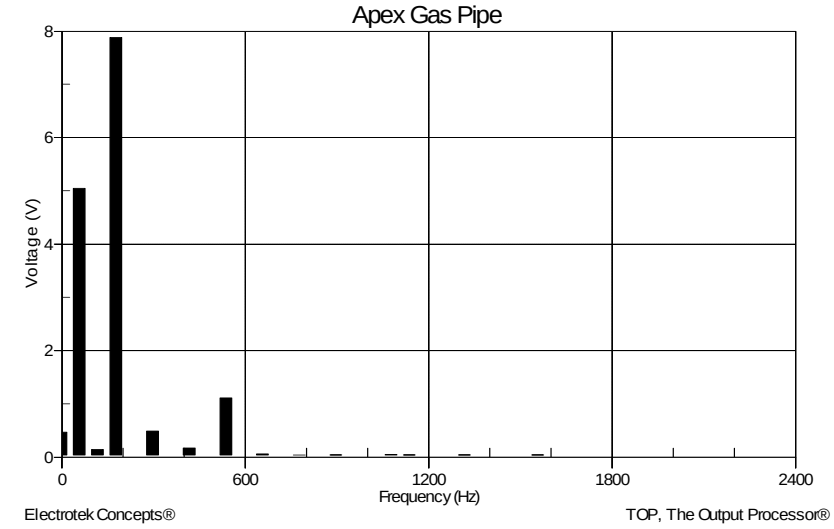
Notable Insights from the Teleconferences

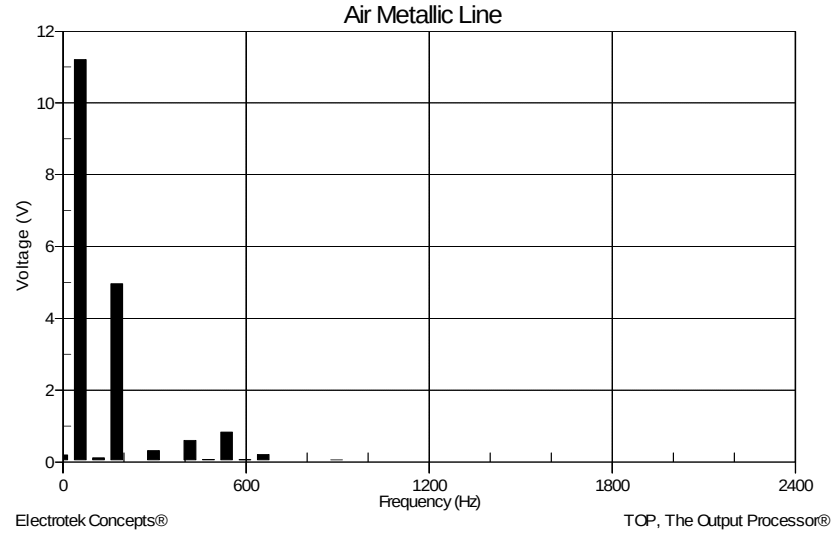
- Problem initially appeared to be random – no distinguishable patterns (time of day, season, etc.)
- No single measurement protocol or procedure had been used over the years to document the field evaluations
- Only hand held voltage meters were used during the field evaluations
- With all involved parties on the same teleconference, it was noted that the voltage concerns were more widespread than just the single point in the industrial park where the present complaint was logged

Measured RMS Voltages were Virtually Identical at Gas and Air Pipelines but Waveforms Were Not!

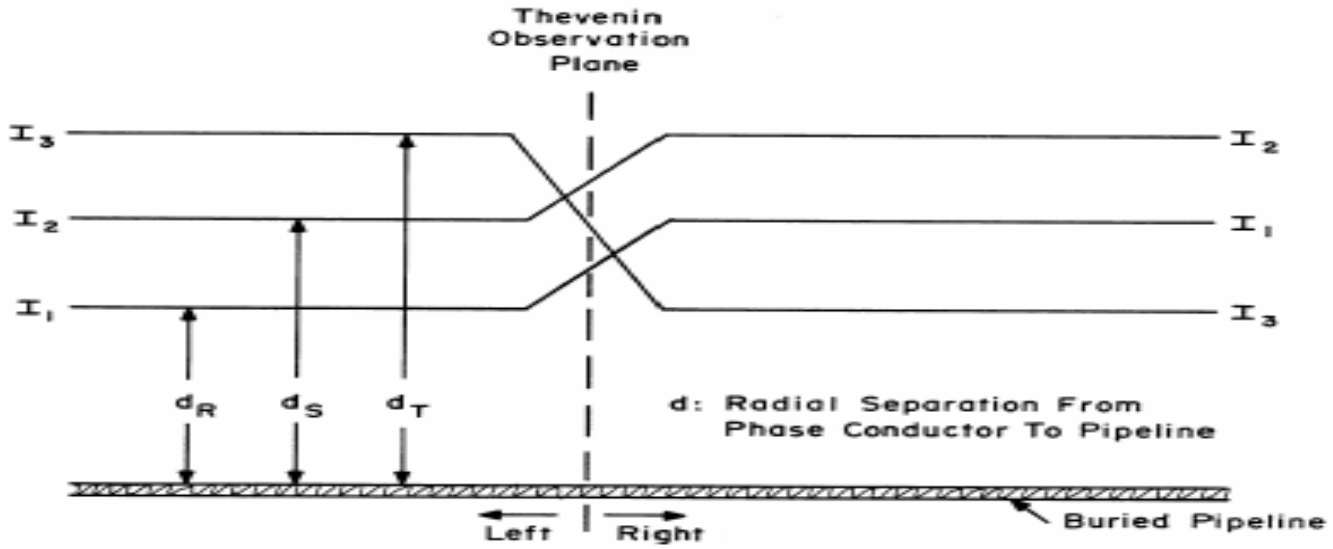




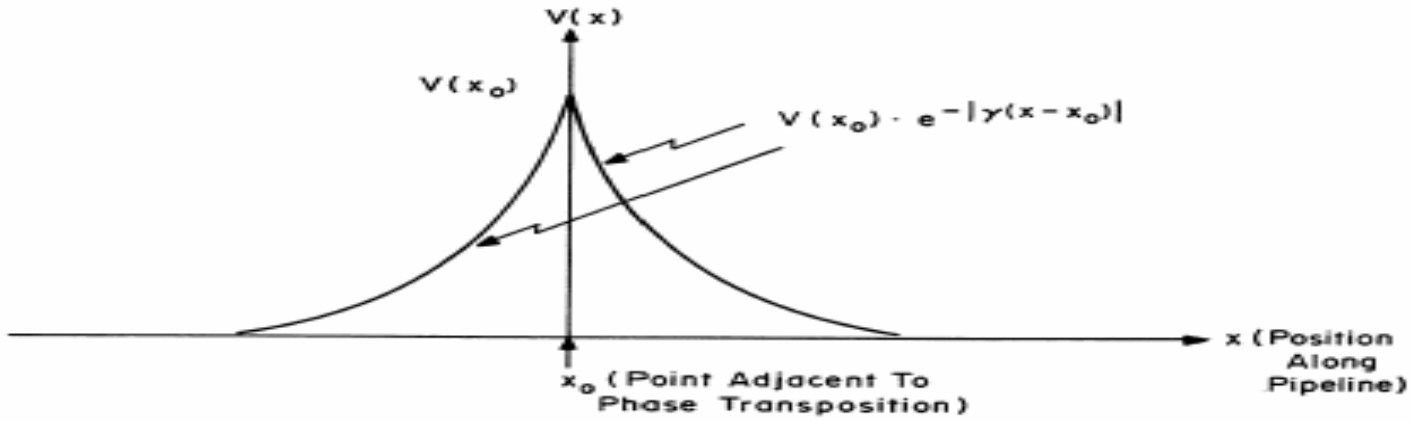




Example of Coupling to a Pipeline EL-3106

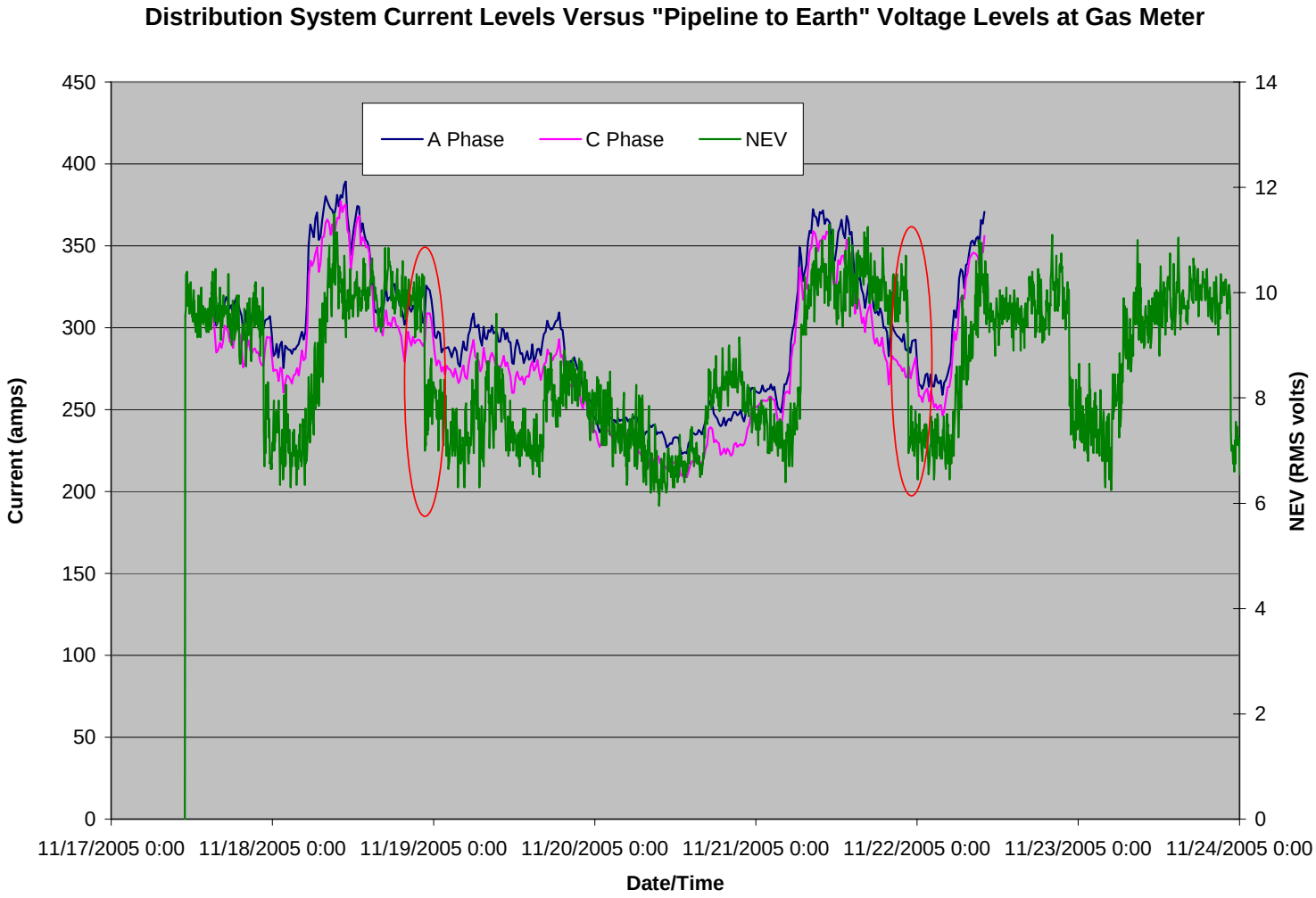


a) Phase Transposition Configuration



b) Induced Pipeline Potential

Correlating 15 Minute Data Samples



Measurement Protocols

- Much of the work in the area of diagnosing and resolving undesirable contact voltage potentials requires accurate and repeatable measurement protocols
- The IEEE Stray Voltage working group has an opportunity to assist the industry in this area
- The protocol is not simply a three page spreadsheet to fill in the blanks
- Considerations range from training personnel to selecting the proper equipment for the task at hand, and implementing the appropriate measurement and documentation procedures

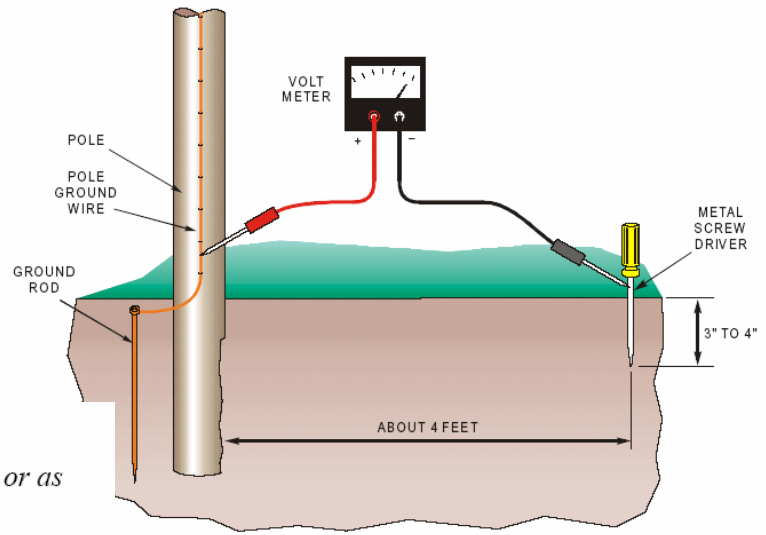
Measurement Protocols

- If done properly, a consistent and repeatable measurement protocol should answer a lot of the questions that may arise during an investigation
  - Why did the voltage I measured last week disappear?
  - What is the source of the elevated contact voltage?
  - Why did the voltage go away when I measured with a resistance in the circuit?
  - Why do I get different readings with two different instruments?
  - Why does the selected reference point change my voltage reading?

Test Protocol Needs

- Sections on the types of test and measurement equipment suitable for the various contact voltage investigations
  - Pen lights to data loggers
  - Calibration requirements and sensitivity
- Sections on basic measurement considerations
  - Remote Earth?
  - Time of Day, Season, Weather
- Sections on different kinds of investigations
  - Energized objects, Pools, Farm animal contact areas
  - Grounding and Bonding assessments
- Section on data analysis (examples)
  - Case studies to support each type of investigation

Equipment and Step by Step and Procedures



Procedure For Urban Investigations (No Gravel or Earth Readily Available):

Note: Depending on the survey objective, this procedure may be as simple as step one only or as complex as the complete set of steps 1 through 9.

1. Using an operational non-contact voltage indicator, such as a the EXTECH LM5, position the unit within 6 inches of the object under test. If the unit indicates the presence of a voltage, go to step 2.
2. Located one or more suitable ground reference points. These ideal reference points are clean, unpainted metallic surfaces such as curb protectors at least 10 feet in length, neutral lugs, bare metal locations on fire hydrants, uninsulated, water pipes, earthed metallic conduits etc.
3. With a high-impedance AC voltmeter, measure the voltage from the object under test to the ground reference.
4. Record the measurement, time it was taken, the ground reference object used and the condition (rusty, painted, scraped metal point, etc.)
5. Select a second suitable ground reference point and confirm the initial reading.
6. If a second suitable ground reference point is unavailable, select other local metallic objects and measure between those objects and the object under test. Attempt to verify the readings taken in 11.
7. Record the second measurement and the time it was taken.
8. Repeat steps 2, 3, 4 & 5 with a DC voltmeter.
9. Repeat steps 2 & 3 with a Harmonics Analyzer and measure and save voltage spectrum info.

Materials Needed:

- Capacitive voltage tester
- High-impedance AC voltmeter
- Screw Driver (or paint scraper)
- Harmonics Analyzer
- DC voltmeter
- Recording Forms
- Watch

Final Comments

- Contact Voltage concerns are created by multiple sources and as such we may need different prioritization depending on the source and the potential current levels
- IEEE Stray Voltage Working Group is in a position to assist the industry with:
  - Measurement procedures and guidelines that result in accurate repeatable results
  - Information on equipment specifications, calibration procedures, and measurement point connection and reference consideration to promote correct measurements
  - Case studies and examples that promote application of optimized mitigation techniques when necessary