

Stray and Contact Voltage

An Update on IEEE PES P1695 Working Group Activities

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Voltages at Publicly and Privately Accessible Locations

(a.k.a. Stray Voltage, Contact Voltage, Neutral-to-Earth Voltage, Urban Stray Voltage, Metallic Object to Earth Voltage, Animal Contact Voltage, Tingle Voltage, etc.)

Technically Complicated

Publicly Misunderstood

Controversial & Emotional

Litigious

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.

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

Voltages found within any electrical enclosure

Voltages found within any substation, manhole, or vault

Measurable Voltages at Locations Accessible to the Public are from Many Sources:

Naturally Occurring Earth Surface Voltage Gradients
(Earth's Magnetic Field)

Lightning Induced Transient Voltages

Radio Frequency Transmission Induced Voltages

Cathodic Protection Voltages

Galvanic Cells Due to Dissimilar Metals

Power System Operation

As a Result of the Delivery and Use of Electrical Energy

Voltages resulting from the operation of:

Transmission Systems

Distribution Systems

Secondary Electrical Systems (Utility & Customer)

Not voltages from the operation of:

Cathodic Protection Systems

Telephone Systems

Radio Stations

Baby Monitors

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.

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.

Normal Voltages

Voltages that exist at accessible locations when the electrical system, from generator to appliance, is operating as intended.

These voltages:

- Can be found everywhere regardless of power system grounding technique.
- Are usually below levels that can be perceived by people and their animals.
- Are often described as "less than 10 volts".
- When perceptible these voltages are generally considered a nuisance voltage, not a hazardous voltage.

Abnormal Voltages

Voltages that exist at accessible locations as a result of the presence of a system fault (i.e. short and/or open).

These voltages:

Are uncommon.

Can be hazardous.

Can be easily detected.

Can be successfully managed.

Stray Voltage:

Historically synonymous with the neutral-to-earth voltages issues that result from normal system operation (e.g. dairy farms and swimming pools).

Historically considered a nuisance voltage, not a hazardous voltage.

No existing IEEE definition.

Consistent with several non-IEEE definitions.

Contact Voltage:

The IEEE 100 definition of "Contact Voltage" is:

Contact Voltage (human safety): A voltage accidentally appearing between two points with which a person can simultaneously make contact. (PE)
[8], [84]

P1695 Working Definition

Stray Voltage:

A voltage resulting from the normal delivery or use of electricity which may be present between two conductive surfaces that can be simultaneously contacted by members of the general public or their animals. Stray voltage is not related to power system faults, and is generally not considered hazardous. (See also Contact Voltage)

P1695 Working Definition

Contact Voltage:

A voltage resulting from power system faults which may be present between two conductive surfaces that can be simultaneously contacted by members of the general public or their animals. Contact voltage is not related to the normal delivery or use of electricity, and can exist at levels that may be hazardous. (See also Stray Voltage)

Outline Draft

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 (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 (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.

Outline Draft (Continued)

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.

Outline Draft (Continued)

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.

Outline Draft (Continued)

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

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 (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: ???

Building Working Group Consensus

- *Stray Voltage: Legislative and Regulatory Activity*
- *Induced Stray Voltages from Transmission Lines*
- *Elevated NEV due to Third Harmonic*
- *Incidental Tree Contact and Publicly Accessible Voltages*
- *Determining Voltage Levels of Concern for Human and Animal Response to AC Current*
- *Stray and Contact Voltage at Swimming Pools*
- *Contact Voltage - New York State Joint Utility Perspective*
- *Contact Voltage from Flooded Equipment*

These presentations and more can be found at the working group web site (<http://grouper.ieee.org/groups/td/dist/stray/>).

How do we define an acceptable exposure in terms of voltage?

- Should it be based on the body impedance of an average man, or that of a small child?
- Should we use dry skin hand to hand impedance, or wet skin hand to foot?
- Should it be set at a level of voltage below perception, at perception, below the let-go threshold, or just below a level that could cause fibrillation?
- Is the measured voltage stray voltage or contact voltage?
- Should the acceptable level be different in a public park than in a transmission line ROW?

Example of Mobile Electric Field Detector

SVD2000 Mobile Contact Voltage Detection System



Operates at speeds up to 20 MPH

Range of over 30 ft.

Sensitive down to 1 volt AC

Enabling technology for detection process

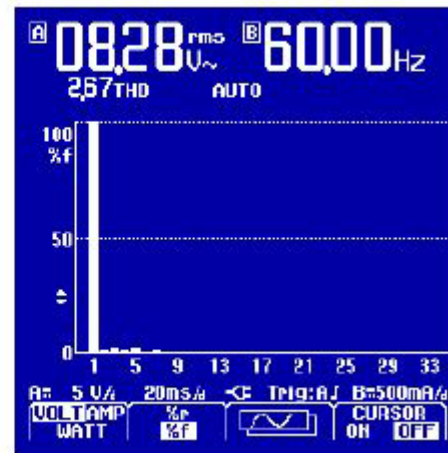
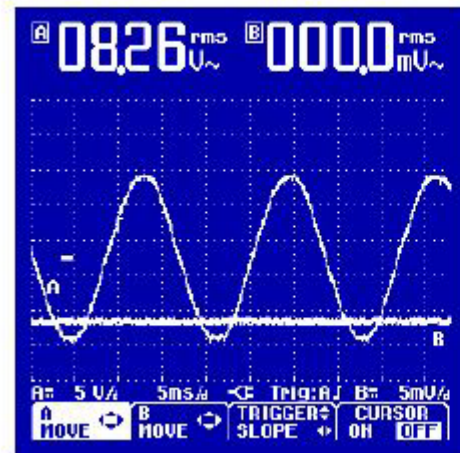
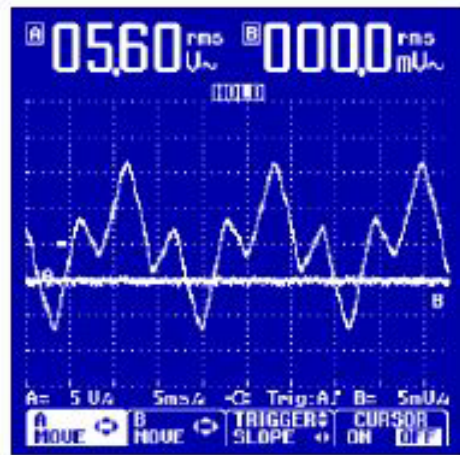
Subject to extensive independent lab testing and certification by NYPSC

Examples of Hand Held Electric Field Detectors

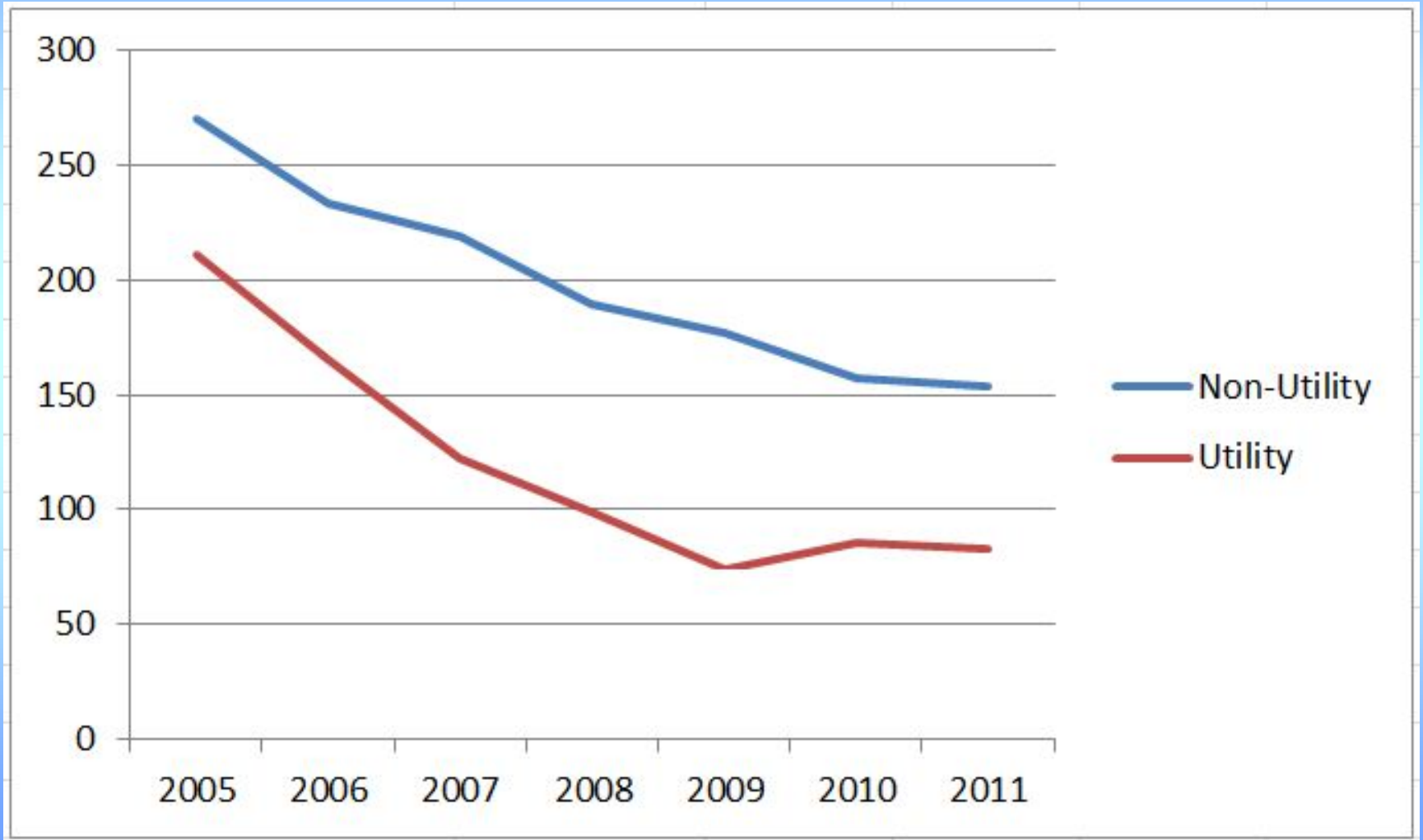


Walker Engineering, Inc. Detector (left), and Power Survey EFD-100 (right).

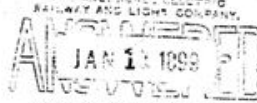
Is it Stray or Contact Voltage?



New York Electric Utilities Substantiated Reports of Public Shock



Milwaukee, January 10th, 1899.



DICTION BY GENERAL SUPT.
LIGHTING DEPARTMENT

To Mr. *Smith*

Mr. O. M. Rau, Chief Electrician,
Building.

Dear Sir:-

Below please find copy of letter this day received from the Board of Public Works, relative to stray current on State Street Bridge. Please have the matter given prompt and careful attention. The suggestion that all bridges used for our service be examined I would also recommend. You will therefore please have the matter thoroughly investigated in order to prevent a recurrence of this complaint.

Yours very truly,

WCV/A

The Milwaukee Electric Ry. & Lt. Co.

By *John I. Beggs*
General Manager

C O P Y

Milwaukee, January 10th, 1899

John I. Beggs, Esq.,
Gen'l Mgr., M.E.Ry. & L.Co., City.

Dear Sir:-

The electric wires on State Street Bridge are in need of readjustment, as horses passing thereover are being daily shocked and thrown by electric currents.

Please have the matter attended to. It might also be well to cause to be made a general examination of the bridges over which your cars pass in order to correct any faults in the electric equipment.

Very respectfully,

(Signed) Paul Muenzberr.
Com'r of Public Works.

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