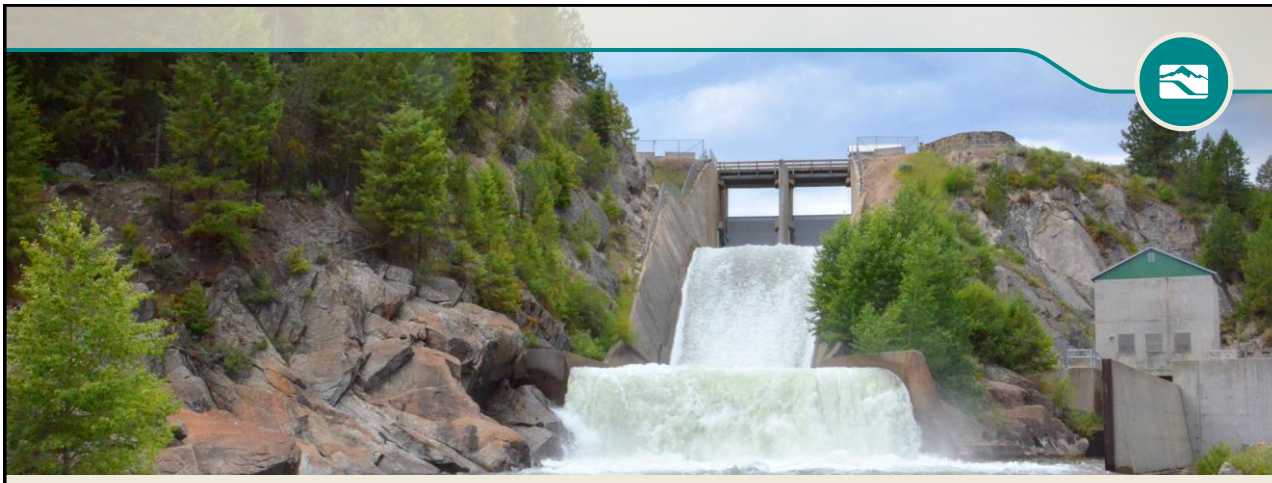

An Introduction to IEEE Standard 1695-2016: *IEEE Guide to Understanding, Diagnosing, and Mitigating Stray and Contact Voltage*

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Outline

- The standard creation process
- The scope and purpose of IEEE Std 1695-2016
- What is in the standard?
- Why you should use IEEE Std 1695-2016
- Some important definitions
- Harmonics – a valuable diagnostic tool
- An example application of IEEE Std 1695-2016

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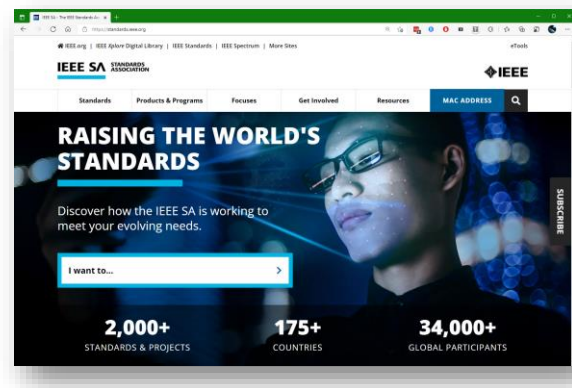
Creating IEEE Standards

- The IEEE is a standard development organization like the NFPA, IEC, and others.
- IEEE standards use an ANSI-approved consensus development process.
- The IEEE Standards Association (IEEE-SA) facilitates and manages the process.
  - IEEE-SA provides online collaboration tools, technical editing, publishing, and other services.
- Anyone can join the IEEE-SA and then submit comments for revision and participate in balloting.



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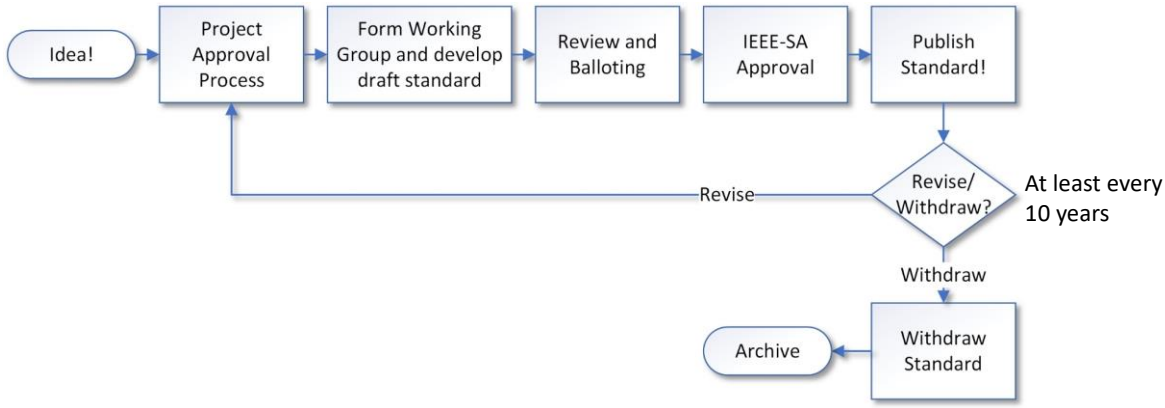
Creating IEEE Standards



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IEEE Std 1695-2016 scope and purpose

- *"IEEE Guide to Understanding, Diagnosing, and Mitigating Stray and Contact Voltage"*
  - Scope:
    - Voltages at accessible locations resulting from the delivery and use of electricity. The guide includes definitions, sources, testing techniques, and mitigation strategies.
  - Purpose:
    - Provide a public, industry-wide guide or standard
    - Provide information regarding potential risk
    - Provide guidance for investigators and others
    - Dispel misinformation
    - Enhance public safety

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IEEE Std 1695-2016 covers…

- Causes of accessible voltages
- Levels of concern
- Remedial actions
- Safety for investigators
- Human and animal electrical sensitivity
- Investigation equipment
- Identifying stray and contact voltage
- Developing Contact Voltage Detection (CVD) programs

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IEEE Std 1695-2016 also includes…

- Specific guidance and protocols for:
  - Contact voltage (light poles, etc.)
  - Confined livestock
  - Swimming pools
  - Marinas and boat docks
- Stray voltage investigation forms
- Extensive bibliography
  - Vetted sources of information for further study.

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Why you should use IEEE Std 1695-2016

- To broaden your scope
  - The standard is indeed a “guide,” providing flowcharts and recommended protocols for a variety of possible exposure situations.
  - Dairy investigators will be familiar with many of the tools and techniques used to investigate exposure voltages in other locations.

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Why you should use IEEE Std 1695-2016

- To increase your understanding
  - The standard includes summaries of human and animal sensitivity research.
  - The standard can serve as a self-directed course and “how-to” manual on stray and contact voltage.
  - Numerous photos and diagrams are used to help explain how stray voltage and contact voltage are produced, and how to investigate it.

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Why you should use IEEE Std 1695-2016

- To boost confidence in your work
  - IEEE standards are respected consensus standards.
  - It's readily available to energy providers, regulators, electricians, and others.
  - The protocols in IEEE Std 1695-2016 are specifically designed so that investigators *"can get accurate readings that are repeatable from person to person."*
    - Note: The standard's protocol for confined livestock facilities follows the Wisconsin Phase II protocol.

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Important definitions

- Contact Voltage
  - *"A voltage **resulting from electrical faults** that may be present between two conductive surfaces that can be simultaneously contacted by members of the general public or animals. **Contact voltage can exist at levels that may be hazardous.**"*
- Fault
  - *"A partial or total local failure in the insulation or continuity of a conductor."*

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Important definitions

- Stray Voltage
  - *"A voltage **resulting from the normal delivery or use of electricity** that may be present between two conductive surfaces that can be simultaneously contacted by members of the general public or animals. Stray voltage is **not related to electrical faults**."*

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Stray voltage versus contact voltage

- Stray Voltage
  - The result of normal voltage drop in neutral conductors, neutral-to-earth voltage, and neutral-to-ground bonding – nothing is broken.
  - An investigation may conclude that the stray voltage does not exceed some threshold and no mitigation is required.
- Contact Voltage
  - The result of a fault – something is broken.
  - Finding and repairing the fault is required to resolve the contact voltage issue.

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Stray voltage versus contact voltage

- The standard uses “accessible voltage” or “exposure voltage” to describe unclassified voltages.
- An exposure voltage may be:
  - Stray voltage
  - Contact voltage
  - Both

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Stray voltage versus contact voltage

- The standard provides extensive guidance on distinguishing stray voltage from contact voltage.
- Voltage level alone is not sufficient to conclusively distinguish stray voltage from contact voltage.
  - What started as a *partial* failure in the insulation or continuity of a conductor could progress to a *total* failure.

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More definitions

- Qualified reference
  - *"A measurement reference point that has been verified to be at zero potential relative to remote earth and have a low impedance pathway to the earth."*
  - i.e., A reference rod for urban situations.
  - The standard includes a process for qualifying a reference point.

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Harmonic analysis – a valuable diagnostic tool

- In addition to measuring the voltage magnitude with and without a shunt resistor, measuring the voltage's total harmonic distortion (THD) and harmonic content can help determine its source.
- The earth, metal objects, and conductive surfaces are generally resistive.
- **An exposure voltage <u>will have the same</u> THD and harmonic content as its source.**

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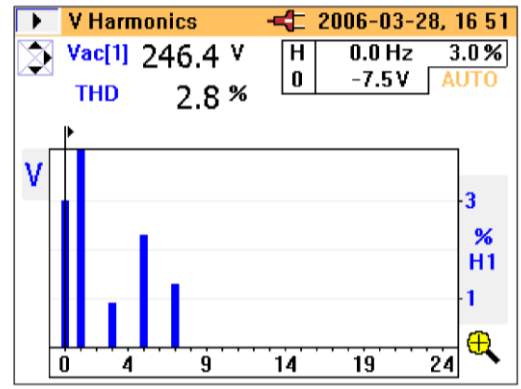
Using THD and harmonic analysis

- Phase conductor sources:
  - THD is typically less than 5% and rarely over 10%.
  - Largest voltage component will be the system fundamental frequency



THD = 2.8% for this line-to-line service voltage measurement.
(Screenshot from Fluke 345)

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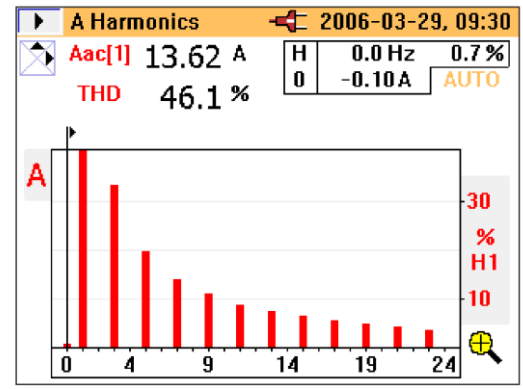
Using THD and harmonic analysis

- Neutral-grounding system sources:
  - Neutral current and the voltage drop it creates may have a high THD
  - Largest voltage component may be 3rd harmonic (180Hz), especially in well-balanced three-phase systems.
  - Your meter can't measure the harmonic spectrum or THD? - Push the Hz button.



THD = 46.1% for this neutral current.

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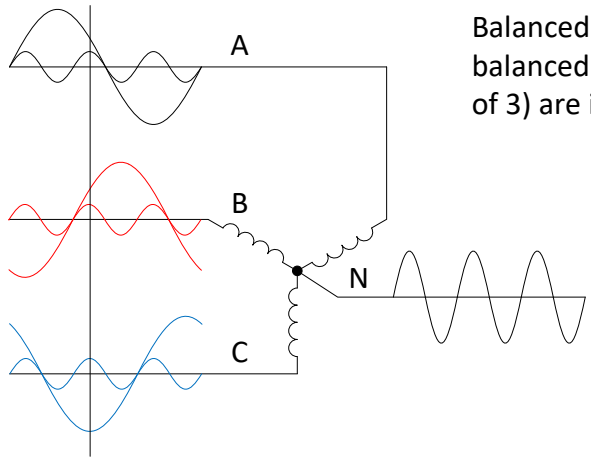
Using THD and harmonic analysis
Why the neutral current may be mostly 180Hz



Balanced fundamental (60Hz) currents sum to zero, balanced triplen harmonic currents (odd multiples of 3) are in-phase and add in the neutral.

Neutral current = 300% of third harmonic phase current but has no fundamental current.
3 x 60Hz = 180Hz.

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Using THD and harmonic analysis

- THD alone, is also <u>not sufficient</u> to conclusively distinguish stray voltage from contact voltage.
- Voltage measured with and without a shunt resistor, AND the THD or harmonic content of that voltage can help the investigator decide where to continue with their investigation.
  - >10V AC-RMS and <5% THD? – more likely a line-conductor fault
  - <10V AC-RMS and >10% THD? – more likely a result of neutral voltage drop

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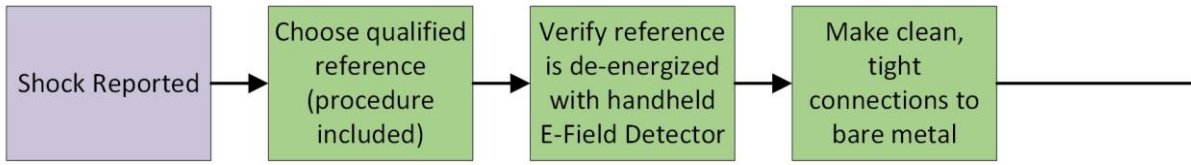
Example application of IEEE Std 1695-2016

- You're called about someone reportedly feeling a shock at a streetlight pole during the day. We'll follow one path through a flowchart included in IEEE Std 1695-2016.



Setting up to take voltage measurements and characterize the voltage.

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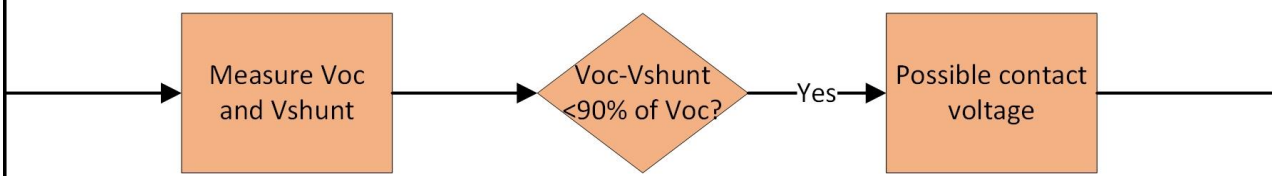
Example application of IEEE Std 1695-2016

- Taking voltage measurements.
- Source is low-impedance – not capacitive coupling and not a fault through a high impedance.



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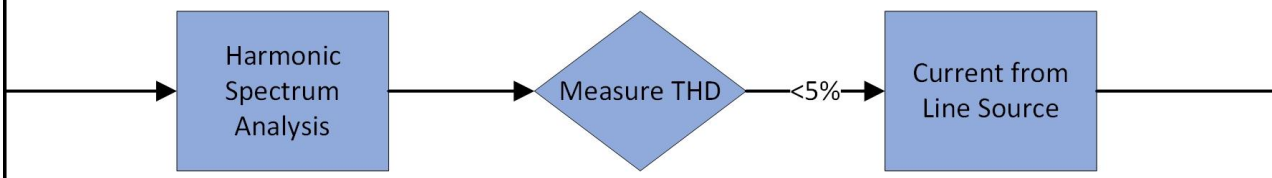
Example application of IEEE Std 1695-2016

- Check voltage THD.
- Low THD suggests a line conductor fault.



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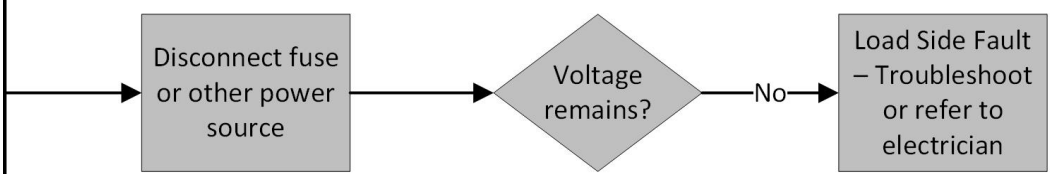
Example application of IEEE Std 1695-2016

- Isolating fault by disconnecting fuse.
- Fault is in the light pole wiring.
- Pole is left safe (fuse removed).



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Example application of IEEE Std 1695-2016

Based on the protocol in IEEE Std 1695-2016, we know where to look to resolve this issue.

[Removed image showing lamp post with line conductor, neutral conductor, and grounding – indicating the location of a short circuit between the line conductor and the lamp post, and a poor or open connection in the neutral conductor]

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Thank you!

You can get your own copy of IEEE-Std. 1695-2016 at **standards.ieee.org.**

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