Using Harmonic Analysis to Classify Encountered Errant Voltages

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Central Hudson Gas and Electric
• Located in the Mid-Hudson Valley of New York
• 300,000 customers in 2,600 square mile area
• 7,300 overhead pole miles and 1,340 trench miles
• Approximately 230,000 facilities tested annually 2006 through 2012.
NYS PSC Order 04-M-0159

• All company-owned overhead distribution, transmission, URD, manhole/pullboxes, substation fences, and municipal owned street lights and traffic signals must be tested.

• Per the PSC Order, a stray voltage is defined as a non-naturally occurring voltage (contact voltage)

• 2008 Order Revision states that utilities must mitigate any stray voltage equal to or above $1 \text{ V}_{ac}$ compared with old standard of $4.5 \text{ V}_{ac}$.

• Since 2009, Central Hudson has been applying harmonic and power quality theory to classify voltages found during stray voltage testing.
Types of Voltage Found in Field

• Contact Voltages
  – Faulted electrical equipment – motors, heaters, etc. where breaker has not operated
  – Inadvertent energization of conductive object – service boxes, manholes, streetlights, etc.

• Naturally occurring
  – Neutral to Earth Voltage – Current flow through neutral resistance
  – Electric Field Coupling – Electric field from overhead line coupling voltage to conductive object in vicinity of electric field.
  – Harmonic Resonance – Power system currents interacting with circuit elements
  – Magnetic Induction – Current on a wire inducing voltage on a parallel pipeline, fence, or wire.
Multi Grounded Wye Distribution

- Primary return path back to the source is generally the system neutral. The system neutral has a voltage associated with it due to the impedance in the wire. The return current that is flowing to earth can typically be 60% of the total return current.
  - The impedance to earth can become very small as the number of grounds increase.
  - By design a flow on the down ground can be expected.
- The neutral and the earth are bonded via a ground and should be at the same voltage potential however a resistance does exist between these two points thus causing a measurable potential or $V(\text{NEV})$.
- The potential between the system neutral and remote earth is known as neutral to earth voltage or (NEV).

$$V_{\text{NEV}} = I_{\text{NEC}} \times Z_{\text{grid}}$$
Examples of Voltage Sources
Contact Voltage - Oscillography

- Smooth peaks and valleys
- Clear 60 Hz sine wave
- No distortion present in reading
Examples of Voltage Sources
Contact Voltage – Harmonic Spectrum

- Less than 5% THD
- Almost all of the harmonic components in the 1st harmonic (60 Hz)
Examples of Voltage Sources
Induced Voltage - Oscillography

- No clear peaks and valleys
- Frequency of waveform not clear
- Distortion present in reading
Examples of Voltage Sources
Induced Voltage – Harmonic Spectrum

- More than 10% THD
- High harmonic components outside of 1\textsuperscript{st} harmonic.
Examples of Voltage Sources
Neutral to Earth (Phase Imbalance) - Oscillography

- No clear peaks and valleys
- Peak and valley values changing
Examples of Voltage Sources
Neutral to Earth (Phase Imbalance) – Harmonic Spectrum

- Dominant Frequency is 180 Hz
- Minimal contributions from other frequencies
Why is classification important?

• With harmonic content analysis:
  – Avoid making unnecessary repairs
  – Prioritization of Repairs
  – Cost Savings can be achieved
  – System Health can be evaluated
Spreading the word

• NYS Joint Utility Petition to Change NYS PSC Order 04-M-0159

• IEEE Working Group 1695

• IEEE Transaction Papers
  – Using Harmonic Measurements to Aid in Source Determination during Elevated Voltage Investigations
  – The Results of Asset-Based Manual Testing of Utility-Owned Objects for Contact Voltage in New York

• January 2012 T&D World Article
Questions?