Utility Stray Voltage Concerns on a Non-NESC System

Aaron Prazan

Roadmap

- California Utility Regulation
- CA GO-95 vs NESC
- Common Construction Modes in California
- Stray Voltage Cases
- Current Techniques for Mitigation

California Utility Regulation

Deregulated Bulk Energy Market

- ISO
- FERC

Regulated Distribution

- CPUC
  - General Order 95
  - General Order 128
  - General Order 154

NESC vs CA GO

NESC

- Published by IEEE for voluntary adoption
- Construction, operation, and maintenance
- OH lines, UG lines & electric supply stations
- Written by/for engineers
- Regular revision cycle

General Orders

- CA regulations for mandatory compliance
- Line construction only
  - No work rules or supply station standards
- Separate orders for OH/UG construction, detailed inspection rules
- More direct language for layperson’s understanding (can be unclear)
- No planned revisions

Treatment of OH Neutral Conductors

General Order 95, Rule 33.3 Ground Connections

A. Effective Grounds

Supply equipment…shall be effectively grounded:

- neutral conductors of low voltage supply circuits
- neutral conductors of supply circuits >750V
- Bond wires
- Lighting arrestors
- Transformer cases

B. Independent Ground Connections

Ground connections of any of the types listed in part A shall not be interconnected with ground connections for equipment of any other type listed…

Treatment of OH Neutral Conductors

GO 95 Rule 59 - Common Neutral Systems

- Requires “CN” designation at each pole/crossarm
- Grounding conductor #4 AWG or greater
- Grounding every 1,000ft along main line and every 500ft on branch circuits with no return loop
- $\leq$3.5 ohm from any point to ground or $\leq$1 ohm from any point to the substation

Treatment of OH Neutral Conductors cont'd

- NESC art 097 allows any of 3 primary and secondary neutral systems (no bias)
  - Isolated
  - Run separately to a sufficiently heavy ground bus connected to ground at >1 place
  - Interconnected using a single ground conductor, provided it has at least 4 grounds per mile
    - Isolated neutrals OK with use of a spark gap device

Effect of Code

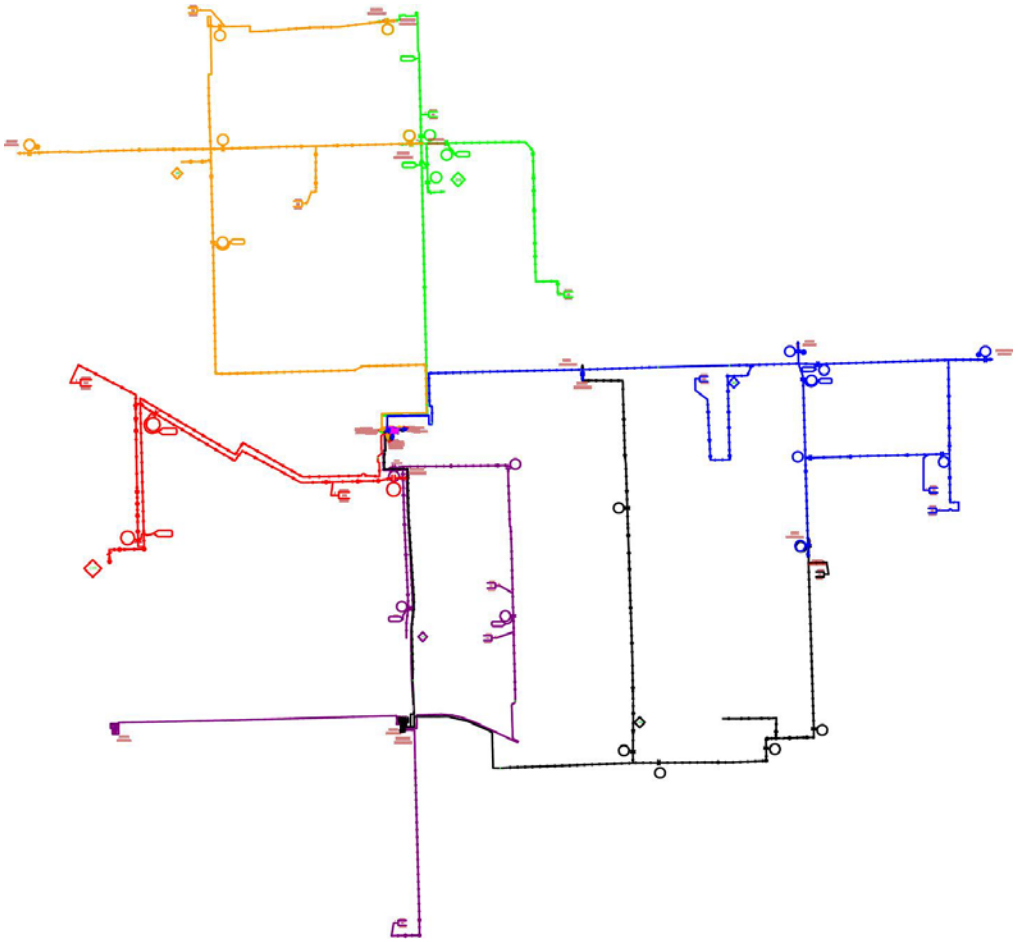
- CA GO 95
  - 4 wire with isolated neutrals
  - 3 wire w/ phase to phase connected loads dominant
  - Mixed use of common/iso neutral in UG areas
- NESC
  - Common neutral nearly universal
  - 4 wire multigrounded neutral with phase to ground loads is dominant construction type

Effect of GO 95 on 4 wire system in CA

- Radial Load
  - Ties normally open
- Networked Neutral
  - Ties normally closed
  - Ground ‘4 x per mi’

Effect:

One neutral with few, poor grounds and multiple parallel paths to source



UG System in CA

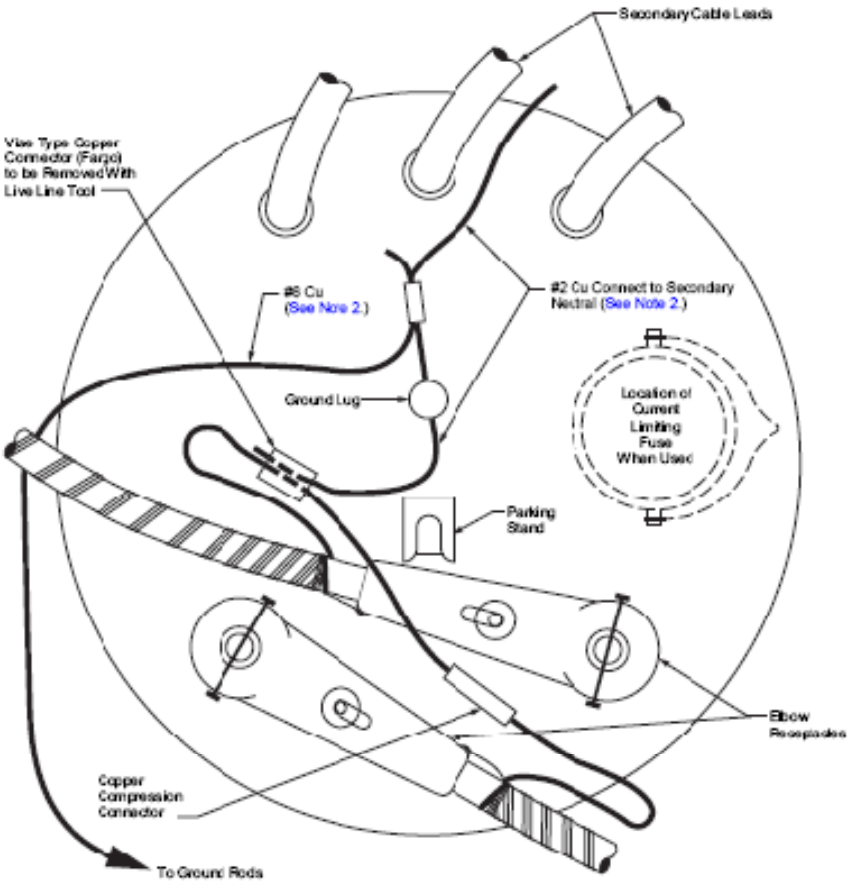
Common neutral required

Cable

- PILC (most removed)
- Bare concentric
  - CIC
  - in duct
- Jacketed concentric since 2002

Effect:

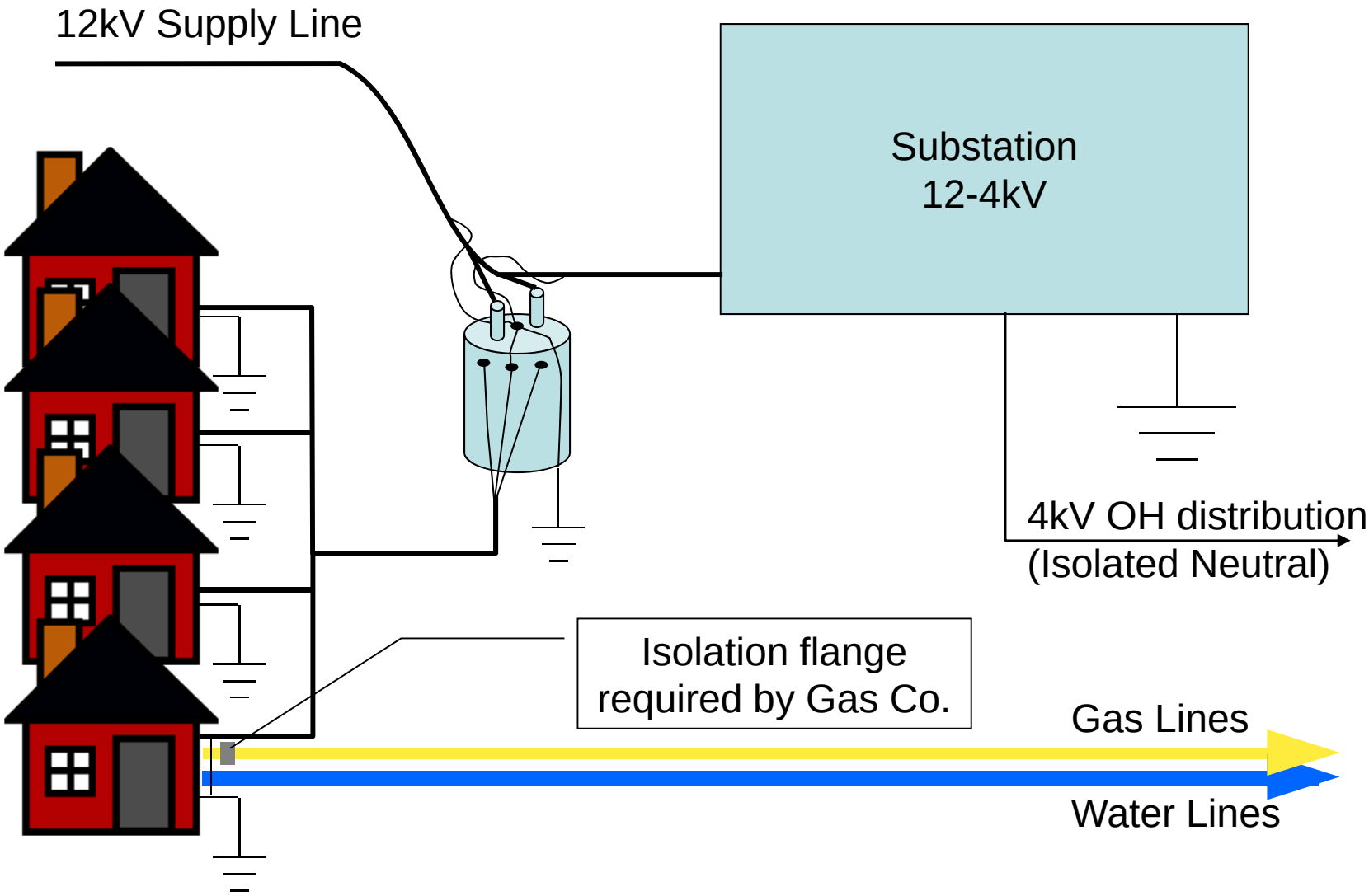
Many parallel paths to ground but older neutrals vulnerable to corrosion



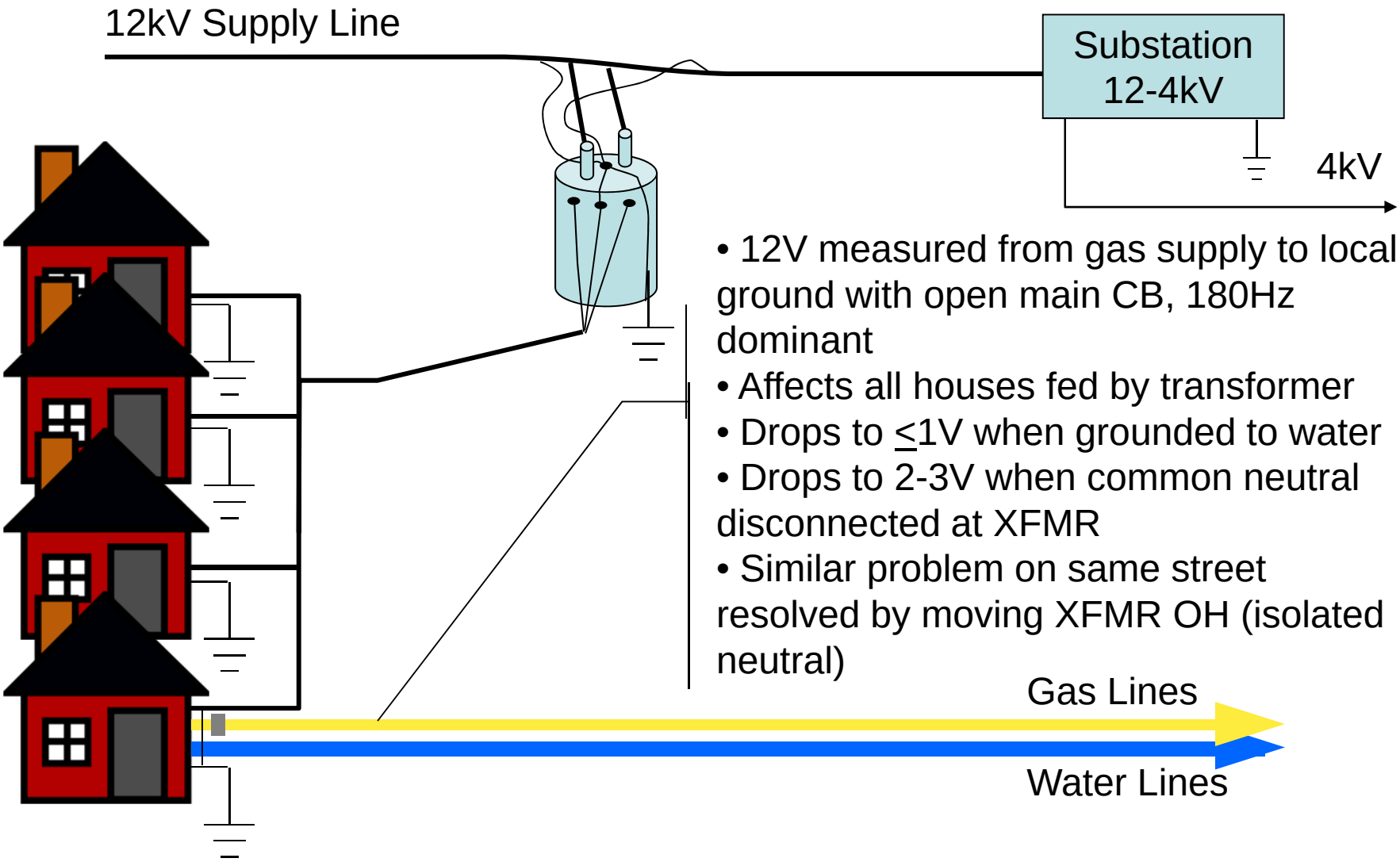
Stray Voltage Cases

- No NEV at end of line by design
- Infrequent
  - <10/yr handled by Power Quality Techs
  - Most often reported as net current on gas/water/comm lines
  - Use of ‘pen’ detectors by non-electric workers
  - EMF reported by interested citizens
  - Shock cases rare

Stray Current Near Substation



Stray Current Near Substation



- 12V measured from gas supply to local ground with open main CB, 180Hz dominant
- Affects all houses fed by transformer
- Drops to ≤1V when grounded to water
- Drops to 2-3V when common neutral disconnected at XFMR
- Similar problem on same street resolved by moving XFMR OH (isolated neutral)

Stray Current Near Substation

- Possible causes
  - Customer wiring
  - NEV
  - Induction via capacitive coupling
  - Faulty neutral forcing D-line return current to take parallel paths to substation

Neutral Maintenance

Many parallel paths around faults

Unintentional parallels at joint use poles

Shared neutrals underbuilt on major routes

Arbitrary use of Cu & Al on distribution, low V, customer wiring

Increasing levels of harmonic return current

Result – possibility of long term degradation without symptom

Mitigation

- No silver bullet
- No safe voltage level
- Approach symptom and disease
  - Supply customer from alternate feed
  - Overall review of grounds on main line
  - Neutral splice maintenance along main lines
  - Concentric testing, cable replacement
  - Cutover projects 4-wire 4kV → 3-wire 12kV
  - 0V not always possible