

ECE 528 – Understanding Power Quality

<http://www.ece.uidaho.edu/ee/power/ECE528/>

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Lecture 42

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Today...

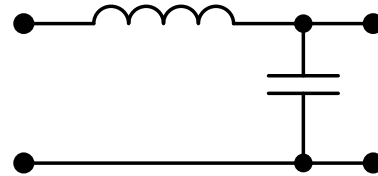
- Power quality instruments and analyzers
 - Issues associated with instrument location
 - Identifying the direction to a fault
- Stray voltage

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How instrument location affects what is recorded

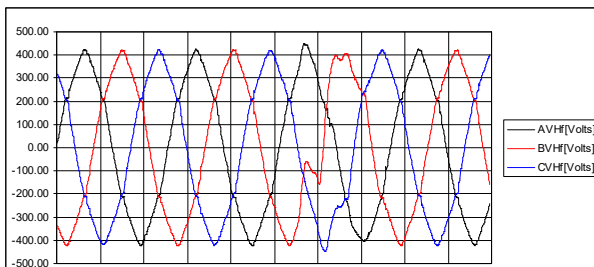
- Transients
 - System acts like an LC low-pass filter – attenuating high frequency signals
- Voltage sags
 - Current change can indicate if cause is upstream or downstream
 - Instantaneous power may make the sag direction more apparent



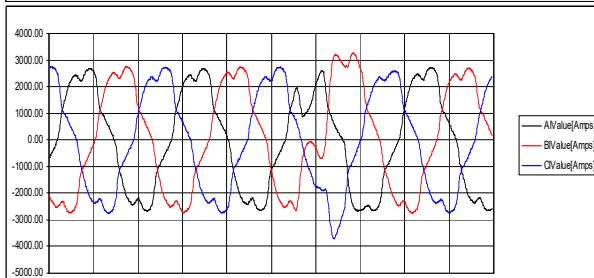
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Event direction?



Voltage



Current

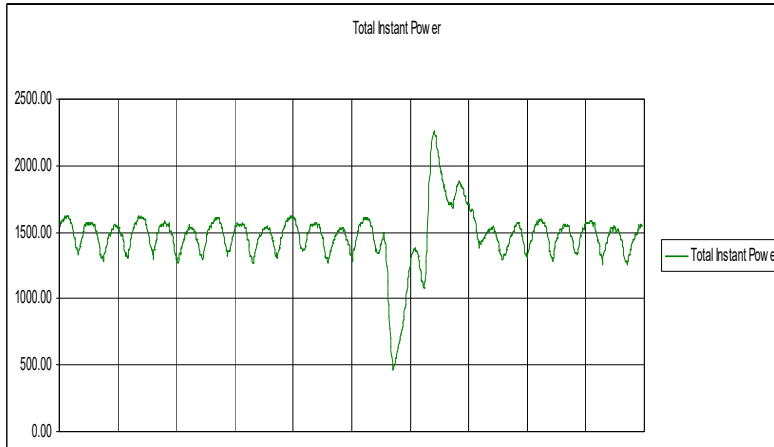
Did the voltage disturbance cause the current disturbance, or did the current disturbance (a change in the load) cause the voltage disturbance?

It's hard to tell.

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Event direction: Instantaneous total apparent power



Same event from previous slide.

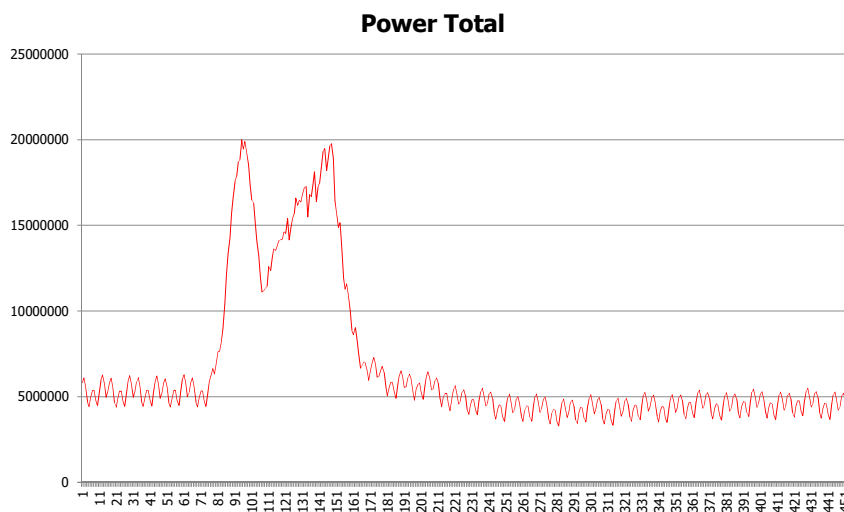
The large drop in apparent power indicates an upstream event.

Instantaneous power climbs immediately afterwards as motors accelerate, and power supplies and drives recharge.

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Event direction?



Using what you know now, which direction is this event; upstream or downstream of the recorder?

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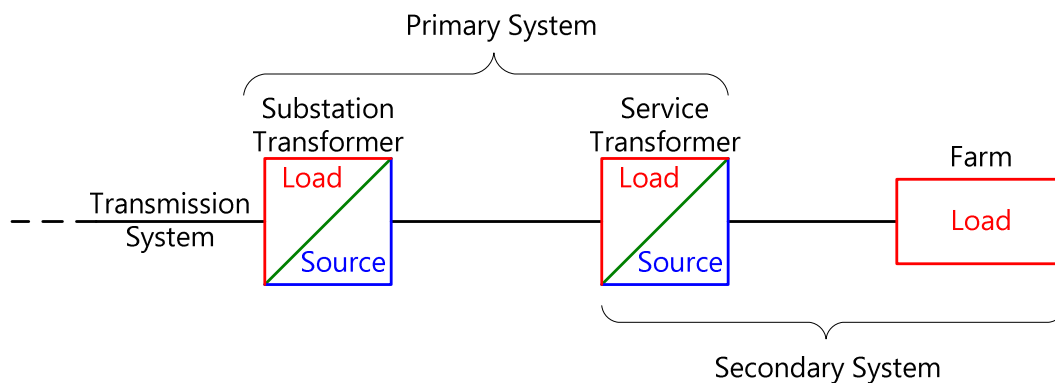
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Understanding Stray Voltage – a brief introduction

- 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.*
- Contact Voltage: (Discussed in lecture 38)
 - *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.*

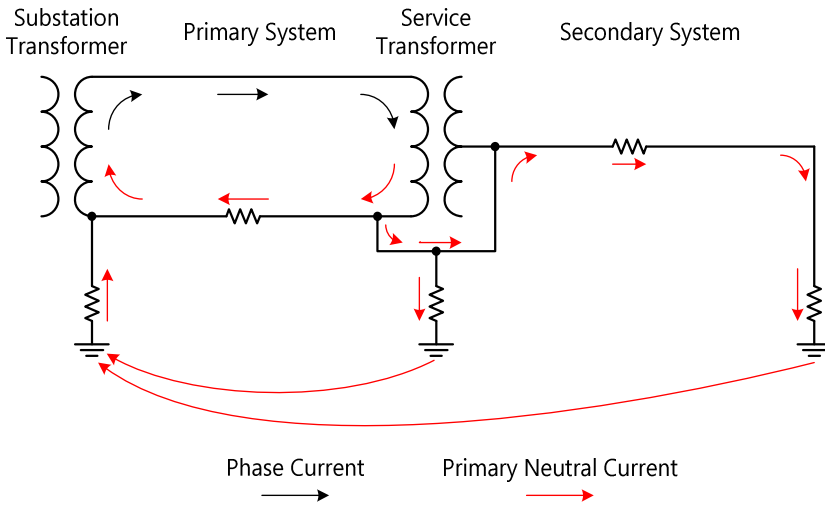
Both definitions from IEEE Std. 1695-2016

Understanding Stray voltage: Sources and loads



Current circulates between a source and load.
 Understanding stray voltage requires understanding the flow of neutral currents between the sources and loads.

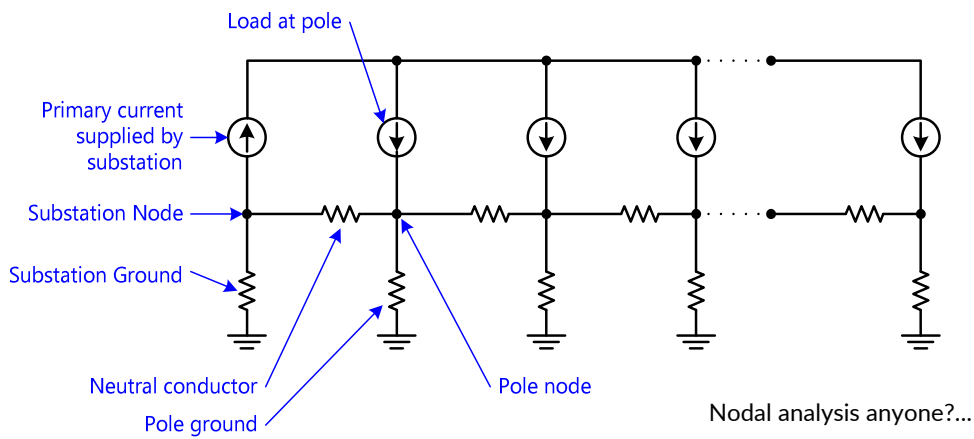
Primary neutral current flow



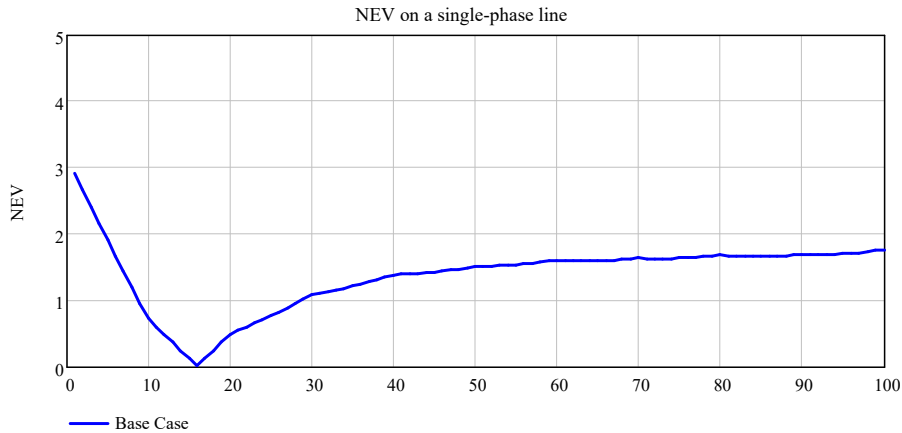
Important observations:

“Source” is the substation transformer and “load” is the service transformer. However, primary system neutral current also flows on the secondary system because the neutrals of both systems are connected. All conductors and earth grounds have impedance. According to Ohm’s Law, there will be a voltage across each impedance in the grounding system.

Modeling the neutral and grounding for a single-phase radial line:



Neutral-to-Earth Voltage (NEV) based on model



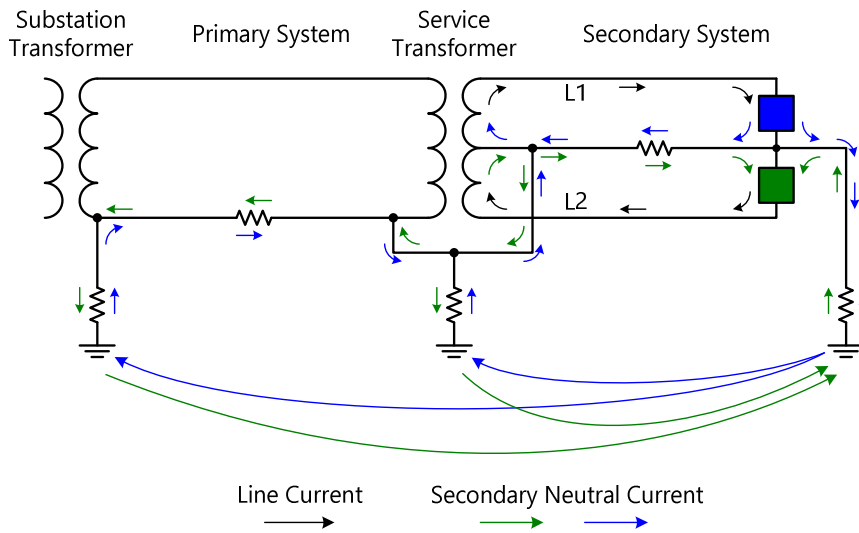
Parameters:
Loading: 3kW at every 10th pole

Neutral: #8Cu

Spans: 330 feet

Grounding:
5 Ohms at load poles
40 Ohms at every 4th pole except load poles
1 Ohm at substation

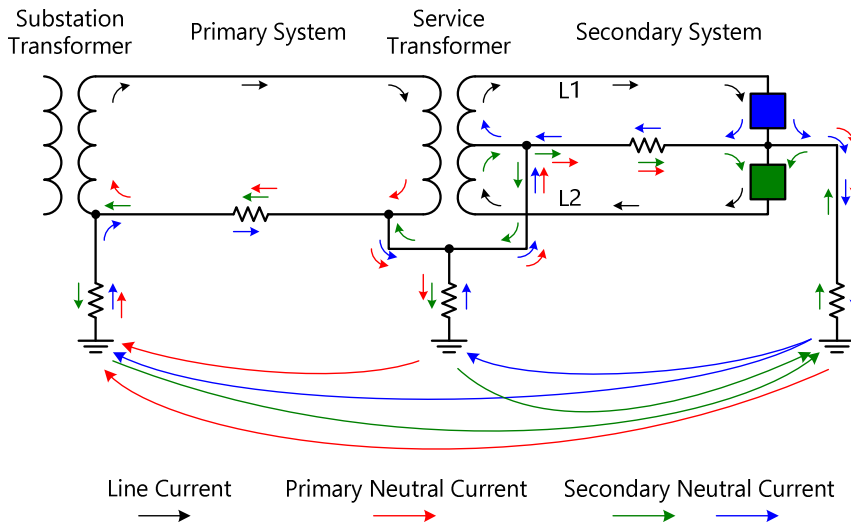
Secondary neutral current flow



Important observations:
“Source” is the service transformer and “load” is the customer’s equipment. However, secondary system neutral current (due to load imbalance) also flows on the primary system.

Primary and secondary neutral current flow

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Important observations:
 Primary and secondary neutral currents can add or subtract. All of the resulting voltages are the normal result of current flowing through impedance. Nothing is broken here.

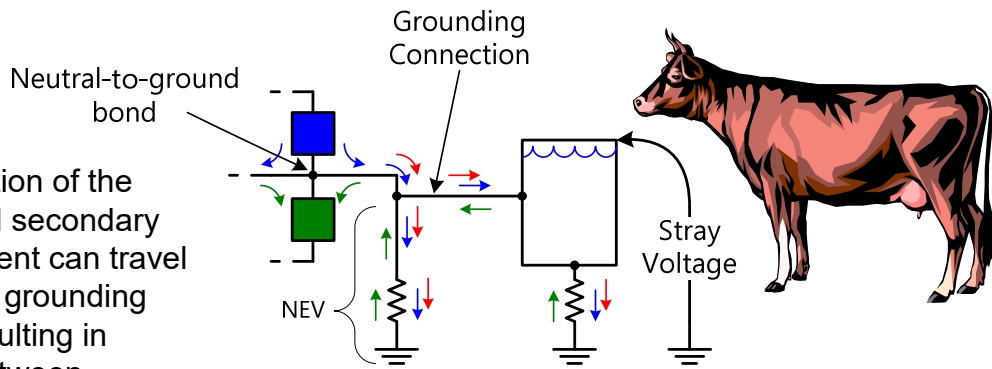
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From NEV to stray voltage

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A small portion of the primary and secondary neutral current can travel through the grounding system, resulting in voltages between conductive surfaces, like the earth and a heated metal water trough



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Stray voltage mitigation: Primary system

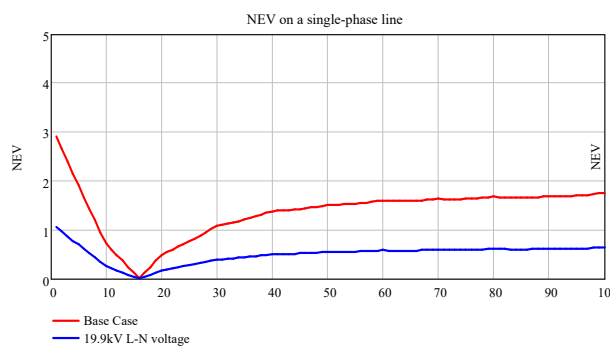
- Two approaches
 - Reduce current on the grounding system
 - Increase voltage of primary system
 - Use 3-phase primary systems and balance the loading
 - Reduce impedance of the grounding system
 - Use large, short, service neutral conductors
 - Increase the size of the primary neutral conductors
 - Increase the primary system grounding

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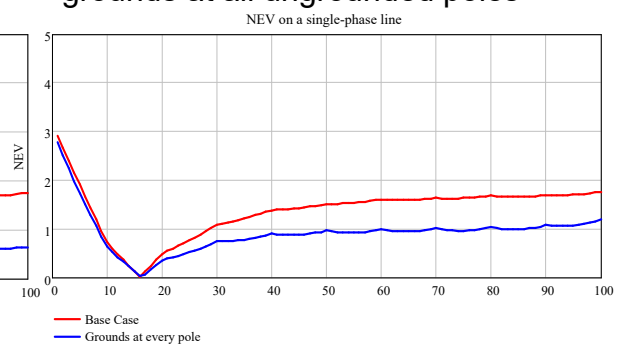
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Stray voltage mitigation: Primary system

Lowered primary current by raising L-N voltage from 7.2kV to 19.9kV



Lowered primary grounding resistance by installing 40-Ohm grounds at all ungrounded poles



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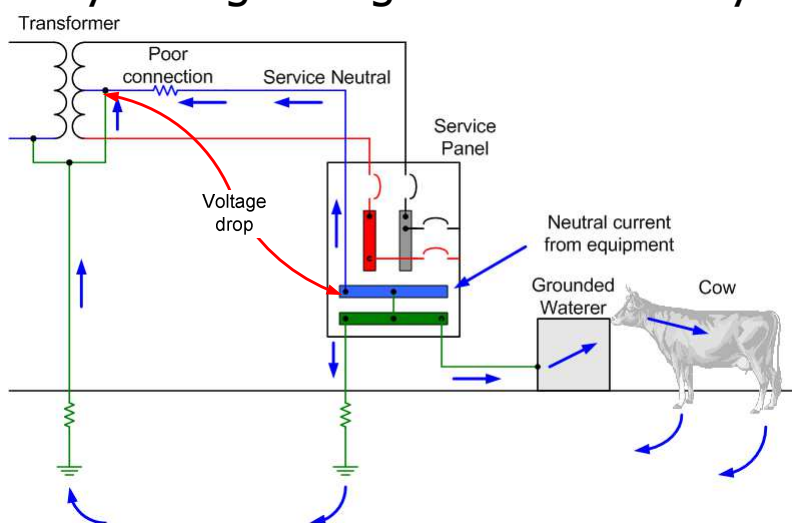
Stray voltage mitigation: Secondary system

- Two approaches
 - Reduce current on the grounding system
 - Balance the load on split single-phase systems
 - Use 3-phase services and equipment
 - Use a single neutral-to-ground bond at the service point with separate neutral and grounding conductors to all downstream locations (NEC)
 - Reduce impedance of the grounding system
 - Large, short service neutral conductors
 - Extensive bonding of conductive equipment (NEC)
 - Equipotential planes in animal confinement areas (NEC)

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Stray voltage mitigation: Secondary system



A poor connection, or a long, small neutral conductor, forces more neutral current into the earth at the service panel, raising NEV at the building service panel and raising the corresponding stray voltage.

Using three-phase loads or line-to-line loads avoids neutral current.

An equipotential plan would put the cow's standing surface and the waterer at the same potential, eliminating the voltage between them. The NEC requires them.

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Stray voltage summary

- There is normally a very small voltage between different grounded objects or grounded objects and the earth.
- Primary and secondary grounding systems are interconnected – changes to one will impact the other.
- After a careful investigation to determine the source of some stray voltage and the circuit parameters, there are steps we can take to mitigate stray voltage using normal electrical principles.

Coming up...

Lecture 43 - Power Quality instruments and analyzers

Lecture 44 – Closing remarks – common final questions