

ECE 528 – Understanding Power Quality

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

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Today...

- HW7 discussion
- More wiring and grounding
 - Troubleshooting loose connections
 - Symptoms
 - Locating loose connections
 - A loose connection case study

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Causes of loose, arcing connections

- Vibration
- Temperature fluctuations
- Other work in the area
- Poor installation
 - Wrong size wire in connector
 - Wire around screw in wrong direction
 - Too little wire in connector
- Corrosion and contamination

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Symptoms of loose connections

- Loose connections may cause many of the common power quality problems we have discussed
 - Voltage sags and undervoltage
 - Additional voltage drop across a loose connection results in lower voltage at the downstream load
 - Voltage swells and overvoltage
 - Additional voltage drop across a shared neutral will result in a voltage swell on other phases
 - Transients
 - Connections may arc, resulting in high frequency transients

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Symptoms of loose connections continued...

- Disturbances may appear to be random
 - No correlation to known utility system disturbances
 - Connection may not be loose all the time
 - arcing can cause melting and “welding” of the connection
 - Voltage drop across high-resistance connections depends on load current
 - May not be noticeable during periods of light loading
 - Some loads may not be impacted by the loose connection
 - Impact of poor neutral connections depends on load balance

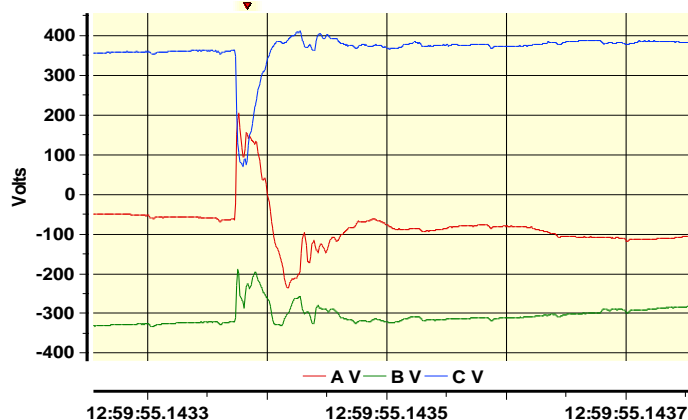
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Identifying arcing in waveforms: Notice the time-scale...

Event Details/Waveforms



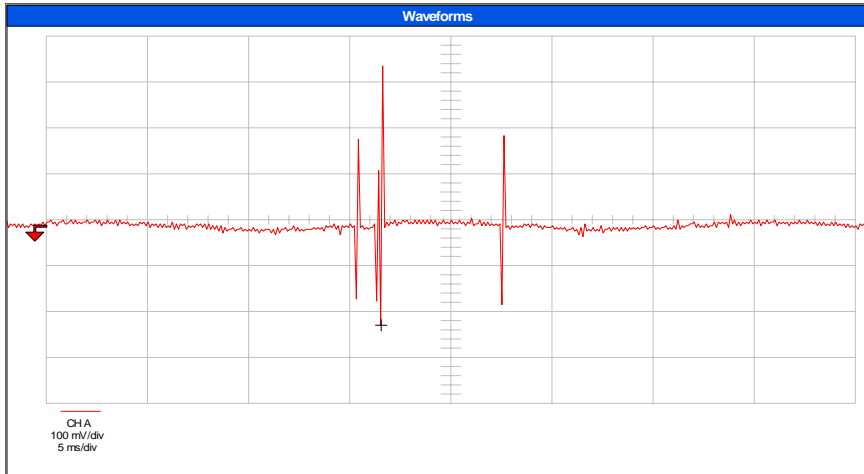
- Nearly instantaneous voltage or current changes indicate arcing
- Power system wiring tends to act like a low-pass filter. The presence of very high frequency components means the arcing is close to the power quality recorder.

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Indication of arcing in a recorded waveform



Recorded with a high frequency current clamp on a grounding conductor

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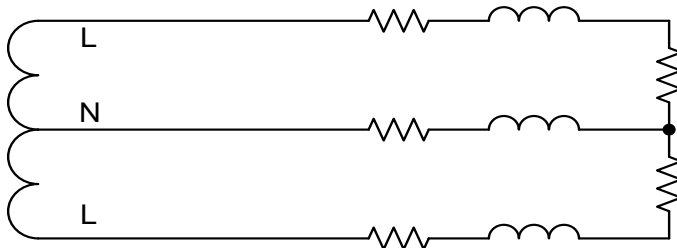
Finding poor connections after symptoms are reported or recorded

- Two main methods

- Look for heat or its effects
- Look for excessive voltage drop

$$I^2 \times R = \text{Watts} = \text{Heat}$$

$$I \times R = V = \text{Voltage Drop}$$



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Loose connections and heating

- “Sensory” inspection – what do you see, hear, and smell?
 - You may see:
 - Melted insulation near a poor connection
 - Arcing at the poor connection
 - Light or dark gray smoke-like stains – may result from arcing and vaporizing of aluminum and copper
 - Heat – infrared thermometer or infrared camera is very helpful
 - You may hear:
 - Crackling or buzzing sound associated with arcing
 - You may smell:
 - Burnt electrical ozone smell

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Seeing loose connections with an infrared camera

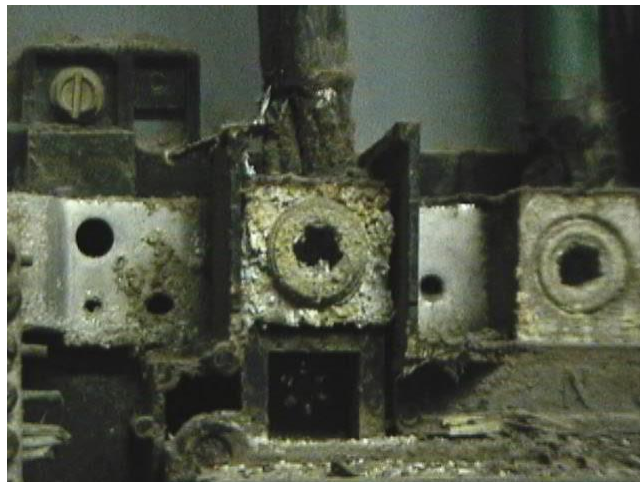


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A contaminated, corroded connection



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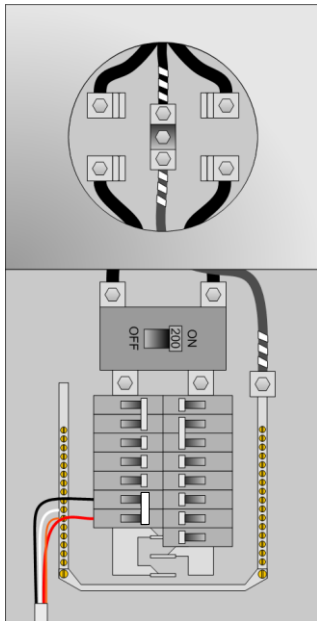
A corroded, broken grounding connection



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Using voltage drop to check connections

- How many connections are between an incoming conductor and a conductor leaving the panel?
- Line:
- Neutral:
- We will use voltage drop to check connections:
- Tools:
 - Resistive load $\approx 1.5\text{kW}$ (hair dryer or similar)
 - Multimeter with voltage probes
 - Receptacle with alligator clips

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Case study: A loose connection

- Customer's reported symptoms
 - Lights in the garage get dim suddenly
 - Light bulbs in other parts of the house seem to get bright suddenly, and are failing after only a short time
 - Disturbances seem random
 - Customer didn't know if neighbors were experiencing similar problems or not

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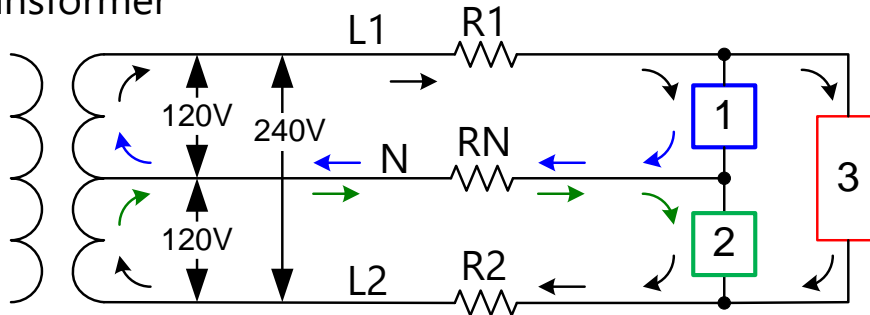
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Simplified diagram of the electric service

Service
Transformer

Service



Note which loads are impacted if the voltage drop across R1, RN, or R2 is excessive.

Excessive voltage drop across R1: Loads 1 and 3 impacted

Excessive voltage drop across R2: Loads 2 and 3 impacted

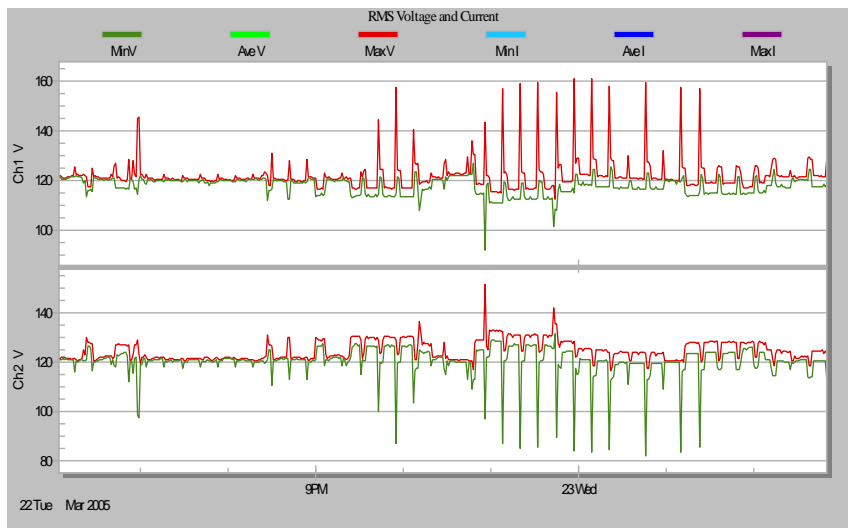
Excessive voltage drop across RN: Loads 1 and 2 impacted, with opposite effects

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Recording at customer's meter socket



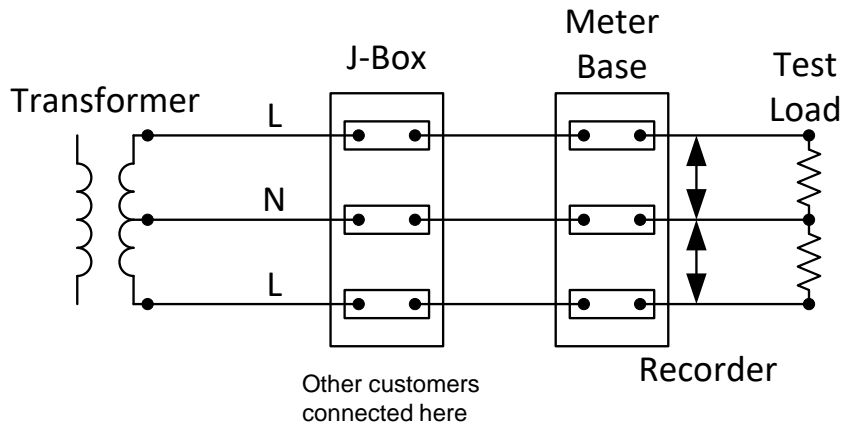
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Actual connections between transformer and meter base

- Which connections do we need to check?



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Case study conclusion:

- Voltage measurements across connections in meter base were normal (approximately the same as shorted leads).
- Voltage measurement across the neutral connection in the junction box for the customer who reported the problem was much higher than normal (> 10V during test.)
- Conclusion - neutral connection in the junction box was loose or damaged.

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Communication circuit problems

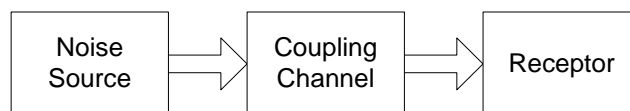
- Signal attenuation – loss of signal strength between the sending and receiving ends
- Coupling (again) – interference from neighboring power or communication circuits
 - Conductive
 - Capacitive (electric field)
 - Inductive (magnetic field)
 - Far field – combined electromagnetic field

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The noise path



- All three components are necessary for a noise problem
- Three possible solutions:
 - Suppress the noise at the source
 - Make the receptor immune to the noise
 - Remove or reduce the coupling(sound familiar?)

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Conductive coupling

- Two or more devices sharing conductors so that current on the conductors due to one device results in voltage fluctuations at the other devices.
- This is why isolated grounds are sometimes used
 - They reduce the “sharing” of the grounding conductor

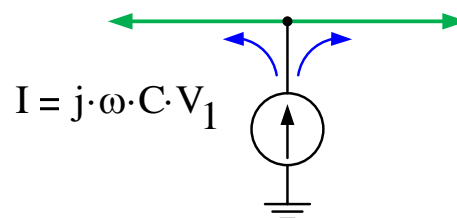
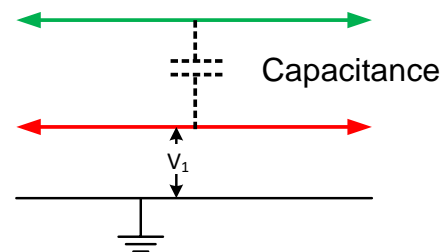
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Capacitive coupling

- Produced by the electric field between conductors (voltage)
- Acts as a current injection point
- Directly proportional to:
 - Frequency
 - Voltage
 - Conductor length
- Inversely proportional to:
 - Conductor separation



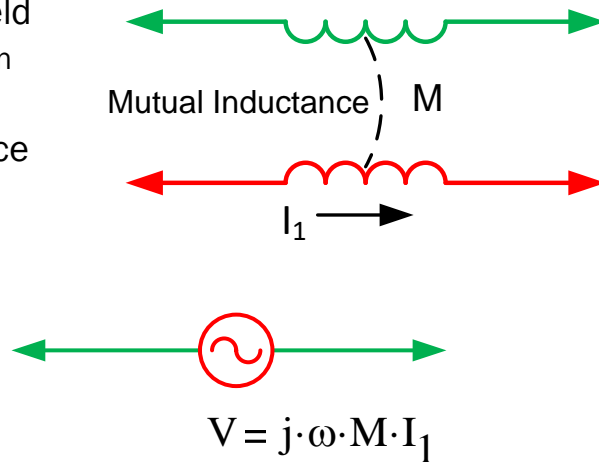
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Inductive coupling

- Produced by the magnetic field between conductors (current in aggressor or source)
- Acts as a series voltage source
- Directly proportional to:
 - Frequency
 - Current
 - Conductor length
- Inversely proportional to:
 - Conductor separation



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UTP – Unshielded twisted pair

- UTP cable is widely used as the standard cable for computer networking and industrial control systems
- Category 5e cable is a networking cable used in Ethernet and other protocols and designed for frequencies up to 100MHz
- How does Category 5e cable (and the communication systems that use it) address capacitive and inductive coupling?

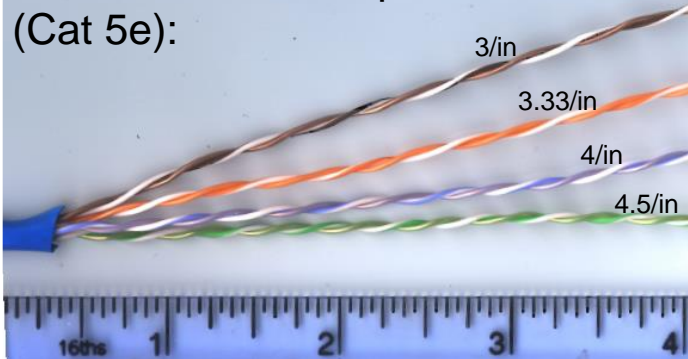
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Overcoming coupling: UTP – Unshielded Twisted Pair

Twist ratios for this particular cable (Cat 5e):



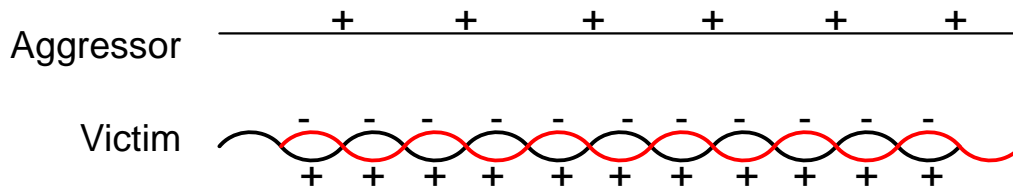
- Construction: Cat 5e
 - #24AWG solid copper conductors
 - 4 twisted pairs
 - Varying “lays” or twist rates
 - No shield

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Benefits of twisting each pair



- Capacitive coupling

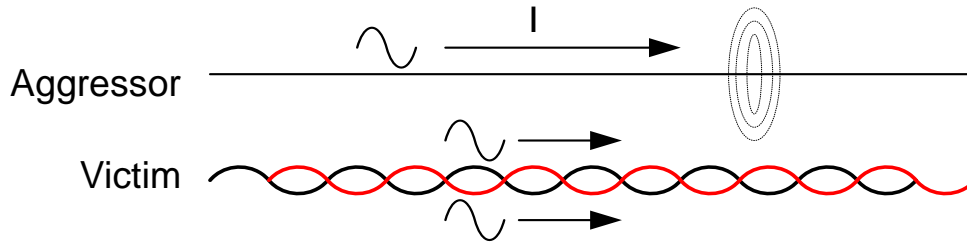
- A nearby “aggressor” circuit is creating an electric field in the area of the twisted pair
- Twists help prevent differential voltage from developing between conductors in the pair

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Benefits of twisting each pair



- Inductive coupling
 - A nearby “aggressor” circuit is creating a magnetic field in the area of the twisted pair
 - Twists force induced EMF to be “common mode”

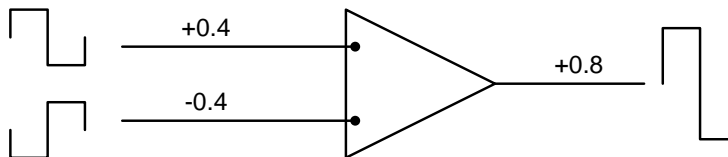
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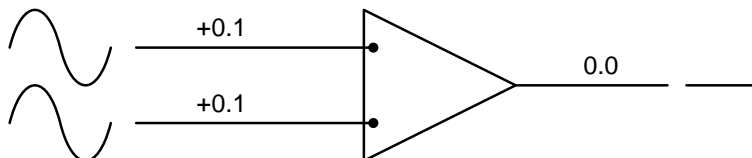
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Differential communication signal and common mode noise

- At the receiver, the differential signal is extracted



- The common mode noise is cancelled



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Other benefits of twisting the signal pairs

- Signal cables can be the aggressor too:
 - One signal pair could be the aggressor for other signal pairs in the same cable or other nearby signal cables
 - Twisting the pairs minimizes the capacitive coupling to other nearby circuits
- Different twist ratios
 - Helps minimize “crosstalk” - the coupling of signals from one twisted pair to another, either in the same cable or other nearby cables

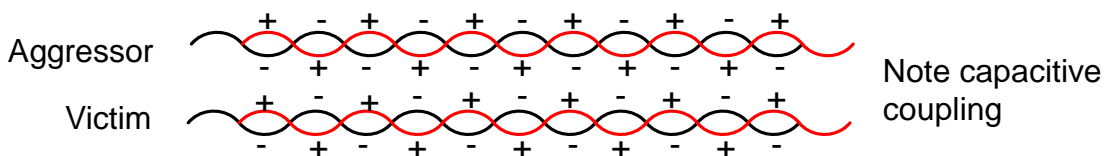
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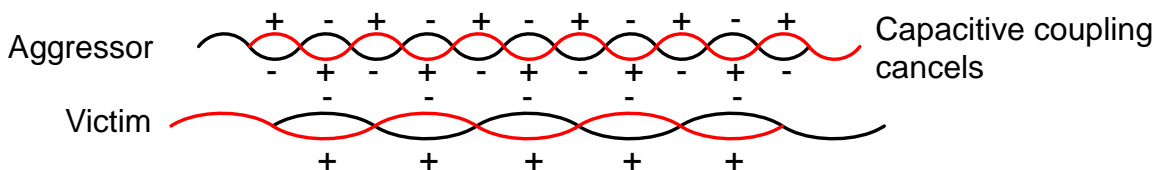
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Benefits of twisting: Minimizing crosstalk

- Same twist ratio



- Different twist ratios



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Coming up:

- Communications circuit performance, the decibel
- PQ recorders, instruments and tools
- Recorder location and the impact on what we record
- Wiring and grounding summary
- Your chance to evaluate your instructor
- Final exam