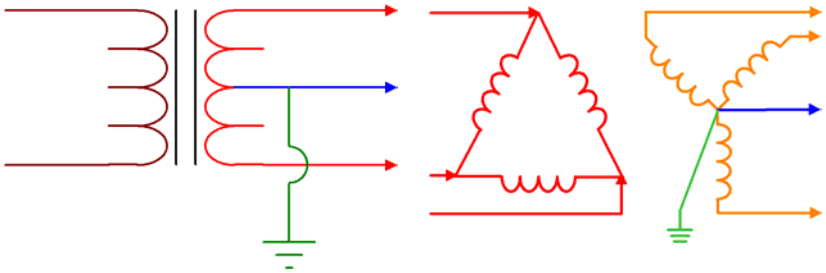
Electrical Services

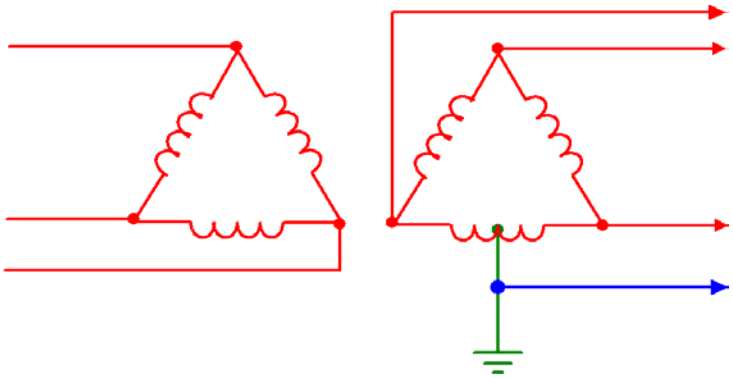
Common Facility Power Systems

- Single phase
  - 240/120
- Three phase
  - 480/277 & 208/120



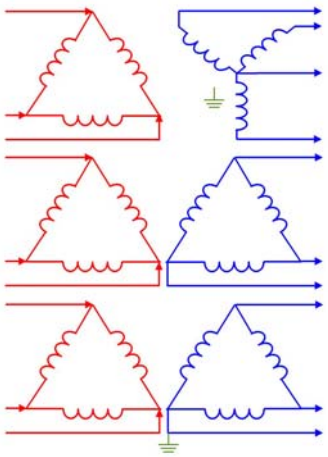
Common & Problematic Service

- Three phase delta voltages (240 delta)
- Single phase voltages (240/120)
- High leg delta (crazy leg, red leg etc.)



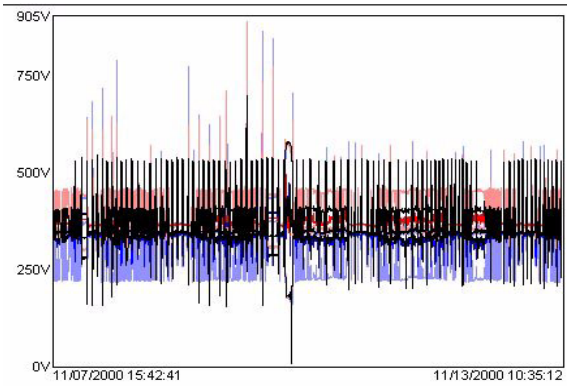
Power/Grounding Variations

- Floated wye
  - –Ground referenced voltages vary with leakage currents
- Floated delta-delta
  - –Ground referenced voltages vary with leakage currents
- Corner grounded delta
  - –One leg at earth potential, others at phase-to-phase potential



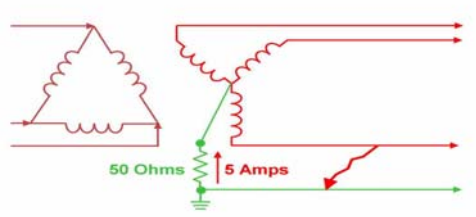
Floated Delta-Delta Service

- Absence of solid ground reference allows ground referenced voltage fluctuations
  - –Load related fluctuations usually within voltage envelope of service
  - –Utility related fluctuations reflect primary voltages
  - –Lightning transients create severe dv/dt



Earthing/Grounding Variations

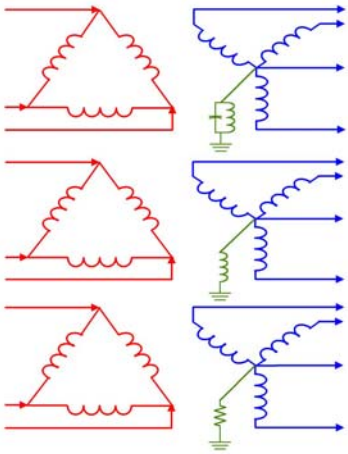
- High-impedance grounded neutral systems
  - –NEC 250-36 [1999-2005]
  - –Typically resistive but may be resonant or inductive
  - –480 to 1000Vac three phase systems with **No** line-to-neutral loads
  - –Ground fault detection required
  - –Impedance sized to prevent arcing faults
  - –Neutral-to-ground bond sized for maximum current per the grounding impedance (ANSI/IEEE 142-1991 Green Book)
  - –Equipment bonding jumper (from equipment grounding conductors to the grounding impedance) shall be sized per 250.66 or 250.36B.



PowerCET CONSULTING EDUCATION TRAINING

Line-to-Ground 1 Ohm Short Test

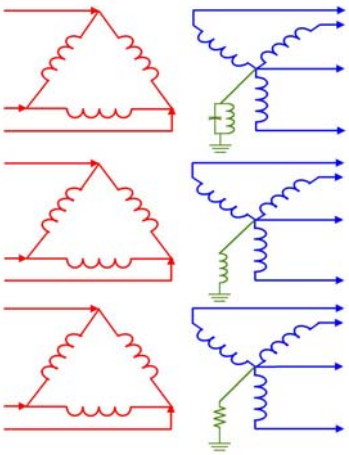
- One Ohm short to ground on output of transformer
  - –Solid grounding
  - –Resistive grounding
  - –Inductive grounding
  - –Tuned tank grounding
- Phase with short approaches zero volts
- Phases without short increase (residual phase voltage plus ground referenced voltage)
- Large phase angle variations



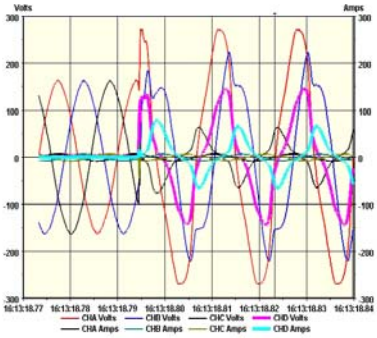
PowerCET CONSULTING EDUCATION TRAINING

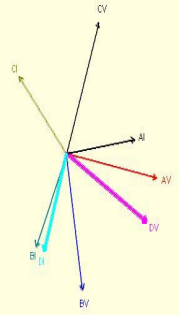
Line-to-Ground Short Test

	Solid Ground	5 Ohm Resistive	10mH Inductive	180 Hz Tank
Phases W/O Short	109 & 103	170 & 167	192 & 146	197 & 153
Phase With Short	72	17	34	30
N/G Voltage	0.39	85	89	114
Fault Current	75A	17A	36A	37A



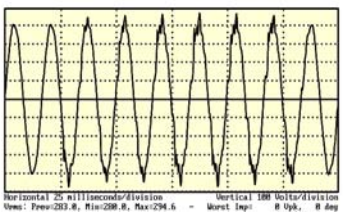
Line-to-Ground Short - Inductive Load

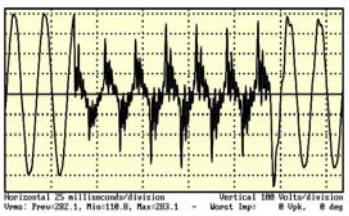




AV=350°, BV=280°, CV=69°, DV=331°,
AI=8°, BI=244°, CI=133°, DI=251°

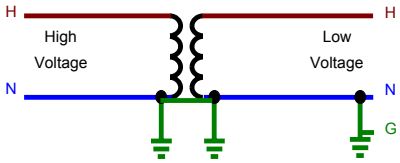
Ugly Voltage Sag & Transients

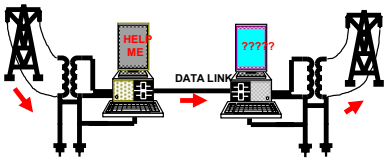


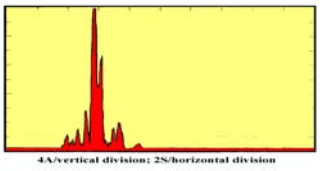


Wye-to-Wye Services

- Facility transformers
- Utility systems

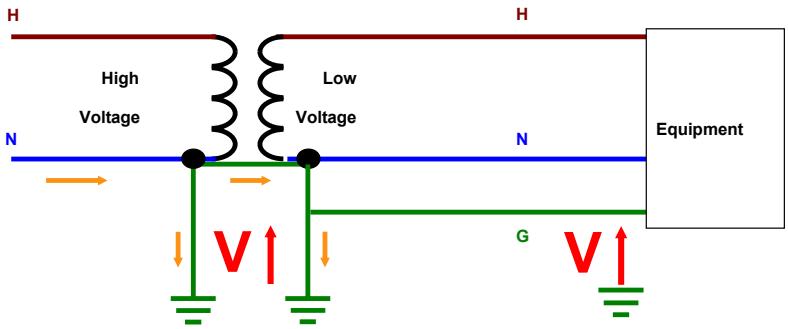




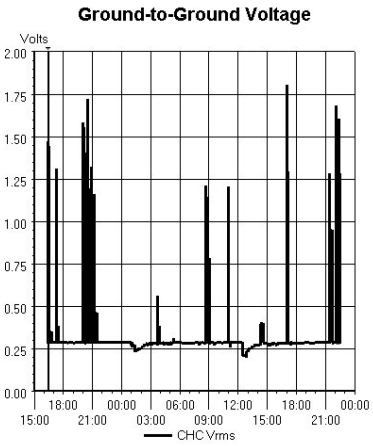


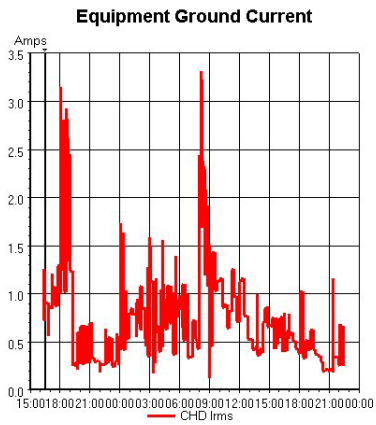
Transferred Earth Potential

- Transferred Earth Potential (TEP)
  - –IEEE Std 142-1991 (Green Book)
    - **•Sections 1.6.4; 1.6.7; & 4.2.6**
  - –Wye-to-Wye & 240/120
    - **•Padmount applications prone to TEP**

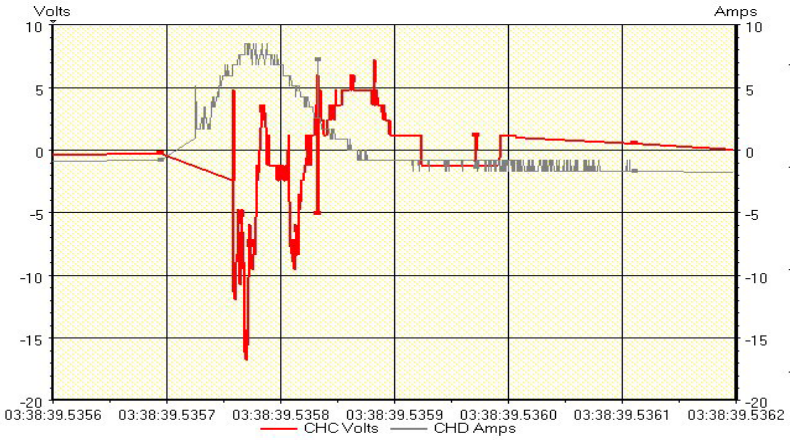


TEP Case History





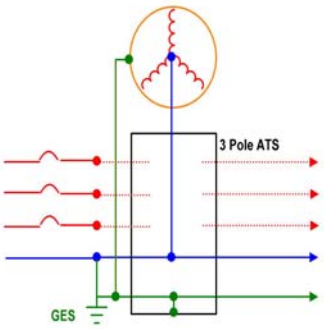
TEP; Lightning Two Miles Distant



Generator Grounding

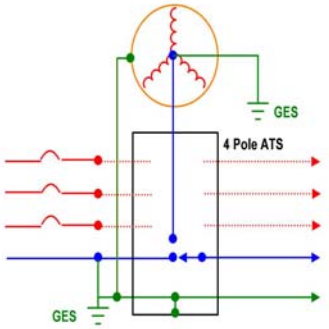
Continual Neutral Generator Setup

- Not separately derived
- 3 Pole ATS
  - –Automatic transfer switch
- GES
  - –Grounding electrode system



Switched Neutral Generator Setup

- Separately derived
- 4 Pole ATS
  - –Automatic transfer switch
- GES
  - –Grounding electrode system

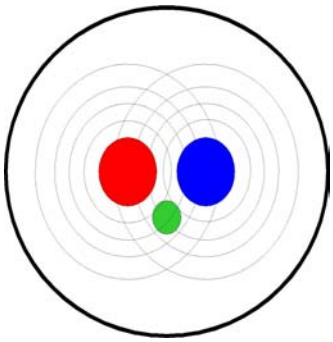


Distribution Grounding

Feeders
Transformers
Separately derived sources
Branch circuit wiring

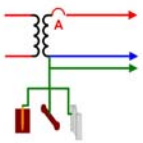
Feeder Grounding

- Permanent, Continuous, & Contiguous
- Ampacity sufficient for fault currents
  - –Conductors
  - –Raceway
  - –Conduit



Grounding Conductor Sizing

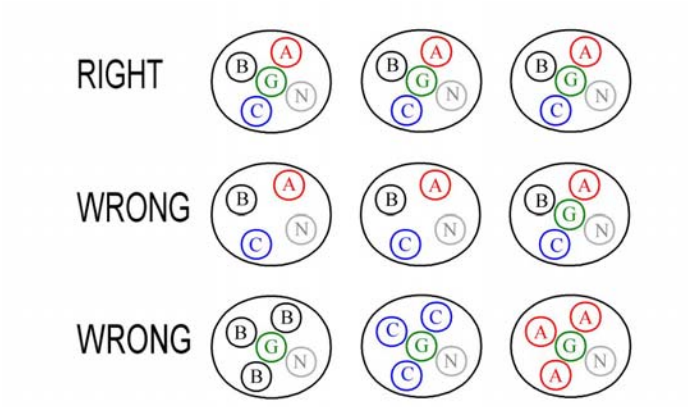
- Article 250-122 [NEC 1999 - 2005]
  - –Wire size (AWG) tied to overcurrent protection **(A)**
  - –If circuit length requires larger conductors, then grounding conductor size must also increase proportionally
  - –In a parallel circuit each grounding conductor must be fully sized per the overcurrent protection for that parallel circuit
  - –Table 250-122 conductor sizing
    - •15A = 14 cu or 12 al
    - •20A = 12 cu or 10 al
    - •100A = 8 cu or 6 al
    - •1000A = 2/0 cu or 4/0 al



Parallel Feeders (1)

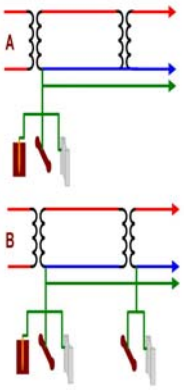
- NEC
  - –NEC 310-4 (1996 - 2005)
  - –Symmetrical
  - –Prevent objectionable ground current
  - –Use same material for conductors
  - –Use same material for conduits/raceways
  - –Maintain same lengths
  - –Use proper conductor placement
  - –1/0 and larger
  - –Grounding conductor sizing
    - •NEC 250-122 (1999-2005)

Parallel Feeders (2)



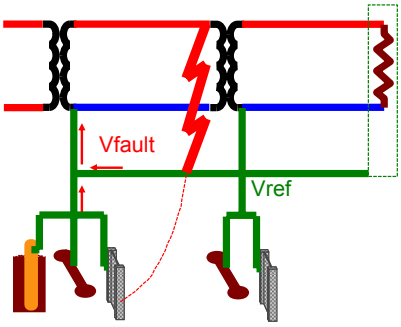
Separately Derived Sources

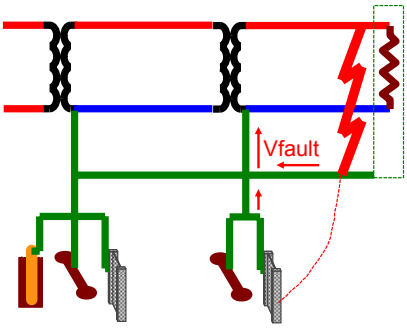
- NEC 250-26 [1996]
- NEC 250-30 [1999 & 2005]
  - –Transformers, UPS equipment, Motor generato
- Figure status
  - –A = Not Separate -- Neutral is continuous
  - –B = Separately derived -- Neutral not continuou
- Bonding
  - –Steel is preferred - NEC 250.30(A)(4) [2002]
  - –Water pipes not preferred unless metal pipes ai continuous and maintained
  - –Bonding to water pipes in areas served
    - •NEC 250.104(A)(4) [2002-2005]



Fault Clearing

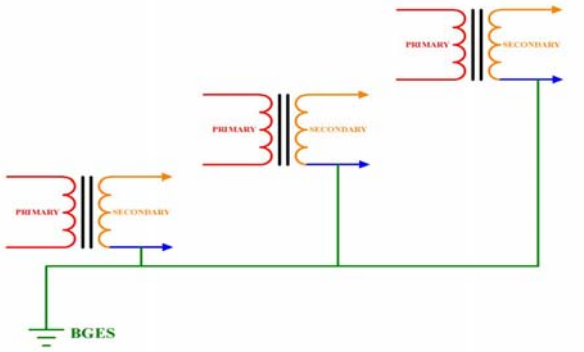
- Primary Fault
- Secondary Fault





Common Grounding Electrode

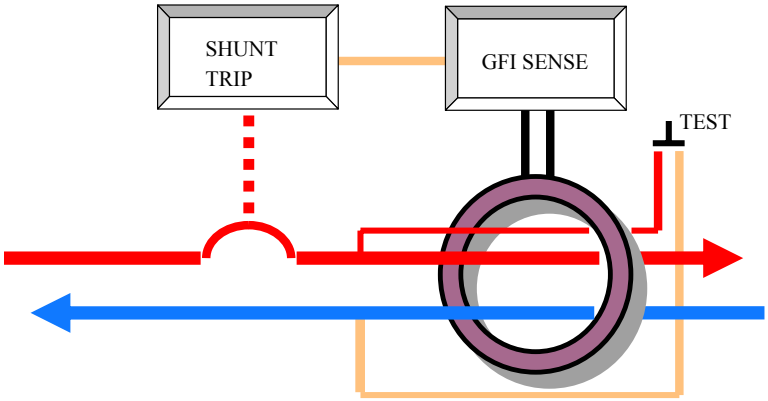
- In facilities lacking structural steel or continuous, metal water piping, a common grounding electrode may be used for separately derived equipment -- NEC 250.30(A)(3) [2002] & NEC 250.30(A)(4) [2005]
- Conductor sizing -- NEC 250.30(A)(2)(b) [2002]; NEC 250.66; Table 250.66 [2002]; NEC 250.30(A)(2) [2005]; NEC 250.102 [2005] - minimum size per 2005 code is 3/0 AWG copper.



Ground Fault Detection

Ground Fault Circuit Interrupt

- Protection for personnel: NEC 210-8 [1996 - 2005]
  - –32 separate references in the 2002 code & 39 references in 2005 code.
  - –**Receptacles, portable devices, bathrooms, etc.**
    - •**5mA response level**

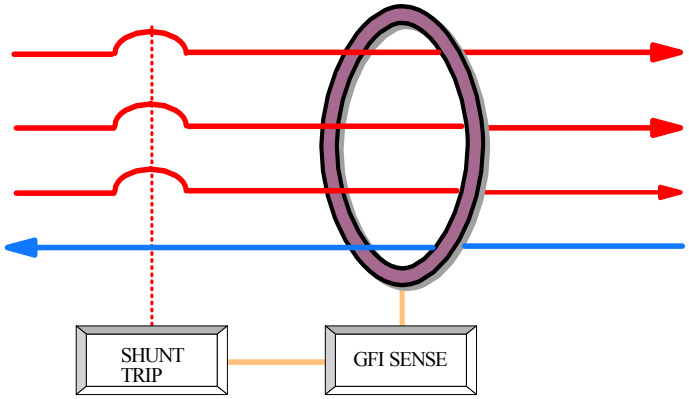


Facility Ground Fault Protection

- Service entrance
  - –Protection for switchgear
    - •NEC 230-95 [1996 - 2005]
    - •>1000 ampere & >150V L-G
    - •Maximum response levels: 1200 amperes & 1 second
    - •Slowest and highest response levels at service entrance
- Exceptions
  - –Service entrances with multiple input breakers (six or less) none of which have ampacities equal to or greater than 1000 amperes.
  - –Continuous industrial services where the interupption of power poses more hazard than relying upon normal overcurrent interruption
  - –Services with high impedance grounded neutral systems.
- Emergency services
  - –Interrupt not required; NEC 700.26 [1996-2005]
  - –Visual and audible signal required; NEC 700-7(d) [1996 & 1999 & 2002]
    - •>1000 ampere & >150V L-G
    - •Maximum response 1200 amperes

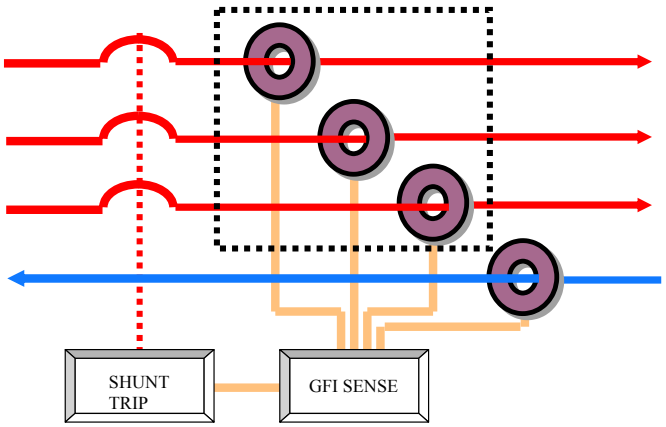
Ground Fault Interrupt 1

- Polyphase -- single CT GFI -- "zero sequence"



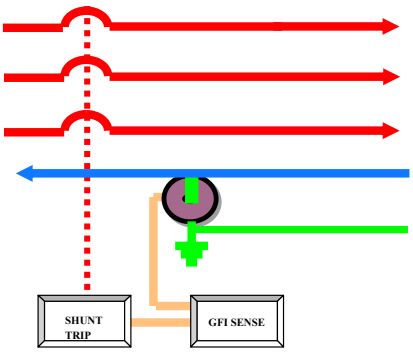
Ground Fault Interrupt 2

- Polyphase -- Multiple CT GFI -- "residual"



Ground Fault Interrupt 3

- Neutral-to-ground bond detect - "source"



GFI Problems

- Magnetic pickup from adjacent circuits
- Voltage and current harmonics vs CT response
- EMI/RFI sensitivity
- Trips settings too low for the application
- GFI on primary of N/G bond in wye-to-wye systems
- Neutral return current flow through N/G bond CT in multiple grounding systems

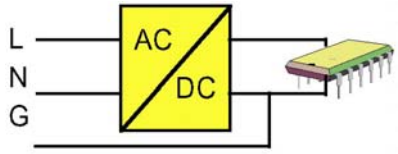
Equipment Grounding

Equipment Grounding

- NEC 250-42 [1996] & NEC 250-110 [1999] & NEC 250VI [2002]
  - –Effectively grounded
    - NEC 250-51 [1996] & NEC 250-2 [1999] & NEC 250.136 [2002]
  - –Continuous & Contiguous - Capacity to safely conduct fault current
  - –Limit voltage to ground (touch potential) - Ensure rapid fault clearing
- NEC 250.4(A)(5) Effective Ground-Fault Current Path
  - –"Electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a permanent, low-impedance circuit facilitating the operation of the overcurrent device or ground detector for high-impedance grounded systems. It shall be capable of safely carrying the maximum ground-fault current likely to imposed on it from any point on the wiring system where a ground fault mayu occur to the electrical supply source. The earth shall not be considered as an effective ground-fault current path."

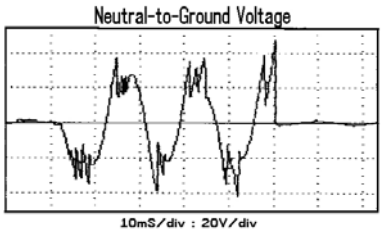
Equipment Performance Issues

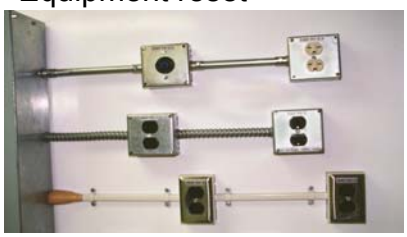
- Complications
  - –Equipment reference
  - –Leakage current
  - –DC common & ac ground
  - –Induced chassis potentials

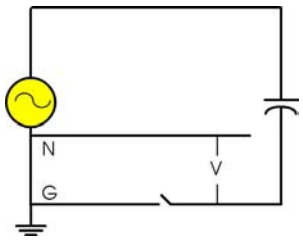


Grounding Discontinuity

- Neutral/Ground Voltage
  - Leakage current
  - Grounding discontinuity
  - Chassis voltage
  - Data loss
  - Equipment reset





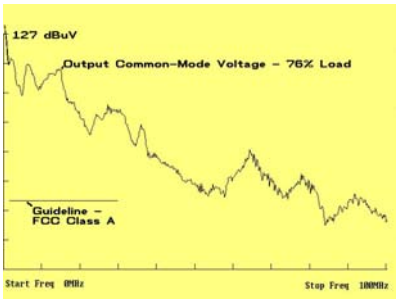


Connection Quality

- Connections become loose with age
- Screw connections
  - Too loose -- bad
  - Too tight -- bad
  - Proper torque -- rare
- Grounding wire essential

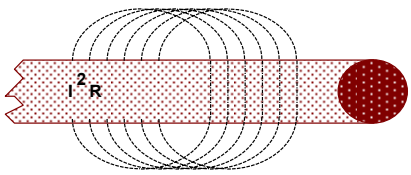
Equipment Emissions

- High frequency emissions
  - –Pulse width modulation
  - –Power factor correction
  - –Clock/logic circuits
  - –I/O circuits
  - –Intentional RF use
- FCC limits
  - –Class A (commercial)
  - –Class B (residential)
  - –9kHz and higher
    - •450kHz is the lower measurement level
    - •127dBuV = 2.24Vrms

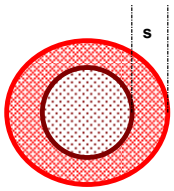


High Frequency Leakage Current

- Kirchoff's Laws prevail
  - –Pulse width modulation (PWM) Noise
  - –Power factor correction (PFC) Noise
- Skin effect & inductance dominate
- Ground is a path, not the terminus



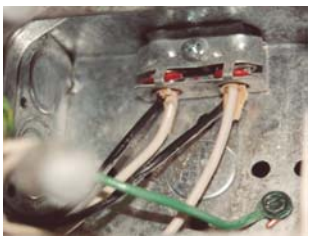
SELF INDUCTANCE



SKIN EFFECT

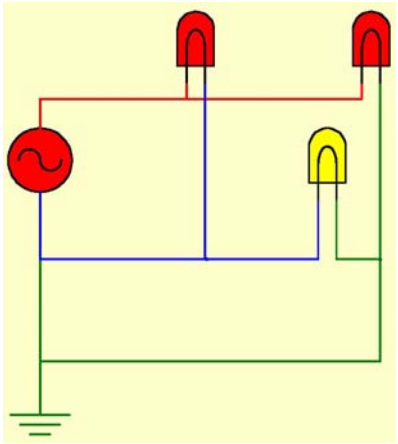
Flexible Wiring Systems

- Intended use
  - Limited length, voltage and ampacity
  - Usual use - lighting circuits
- Types
  - FMC - Flexible metalic conduit NEC 348 [2005]
  - FMT - Flexible metalic tubing NEC 360 [2005]
  - Metal Clad (MC) NEC 330 [2005]
- Grounding
  - NEC 250-118 [1999 -2005]
  - If not listed for grounding
    - 6 feet length (1.83m)
    - Less than 20 amperes



Equipment Leakage Current

- UL limits
  - –3.5mA power frequencies
  - –Formerly 0.5 mA to 5mA
  - –Portable, cord connected devices
- Circuit Testers
  - –2mA maximum
  - –Read & follow instructions!
  - –Disconnect loads before use
- Sources
  - –Capacitive coupling
  - –Wiring errors
  - –I/O circuits



Receptacle Orientation

- NEC
  - No specified position
- IEEE White Book
  - IEEE Std. 602-1996
  - Section 4.2.2
  - "Ground pin or neutral blade up"
  - Reduces accidental contact with exposed live contacts.

Randomly Placed Raceway Wiring

- NEC 300.20 Induced currents in metal enclosures or metal raceways [2005]
  - "Where conductors carrying alternating current are installed in metal enclosures or metal raceways, they shall be arranged so as to avoid heating the surrounding metal by induction. To accomplish this, all phase conductors and, where used, the grounded conductor and all equipment grounding conductors shall be grouped together."

Conductor Types

Cable 1 = NEC/MC
3 phase, 3 grounds, no shield, aluminum interlocked

Cable 2 = NEC/TC
3 phase, 3 grounds, no shield, no armor, tray cable

Cable 3 = NEC/MC
3 phase, 3 grounds, no shield, galvanized interlocked steel

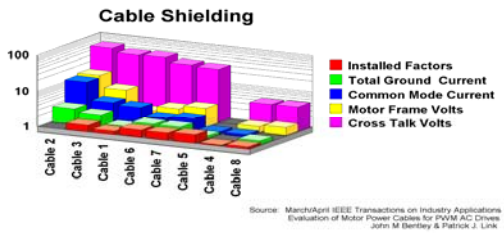
Cable 4 = NEC/MC
3 phase, 1 ground, no shield, aluminum continuous

Cable 5 = NEC/MC
3 phase, 3 ground, copper tape spiral shield, galavanized steel interlocked

Cable 6 = IEC/MCMK
3 phase sectored symmetrical, no grounds, copper tape & wire shield, no armor

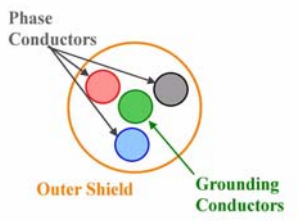
Cable 7 = IEC/MCMK
IEC 3 phase sectored symmetrical, 1 ground, copper tape & wire shield, no armor

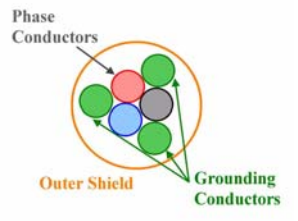
Cable 8 = NEC/MC
3 phase, 3 grounds, no shield, aluminum continuous



Symmetrical Cable Variations

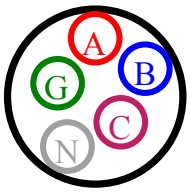
- Equal inductive coupling
  - Magnetic field
- Equal capacitive coupling
  - Electric field
- Shielding controls common mode emissions
- 400Hz applications require symmetrical cabling

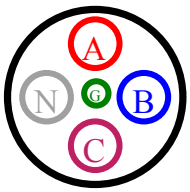




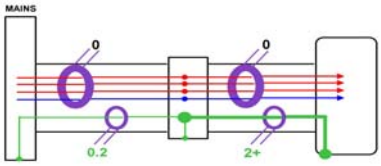
Parity Ground Conductor Sizing

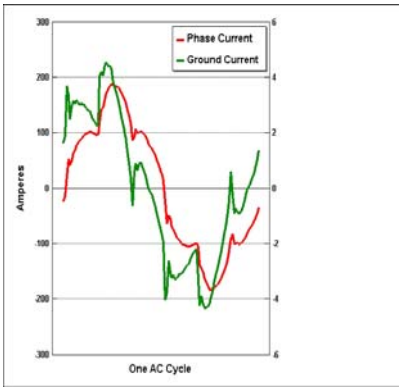
- Parity sizing
  - –Grounding conductor the same size as current carrying conductors
  - –Not a code requirement
  - –Normally a vendor requirement
  - –Attempt to improve equipment reference
  - –Larger conductor size
    - •May magnetically or capacitvely couple
    - •Use may increase ground current





Parity Sizing Problem



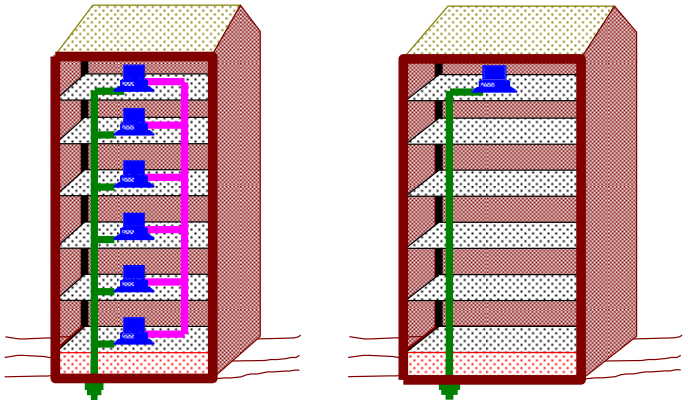


Reference Grounding

Computer rooms
Raised floor environments
Data processing centers

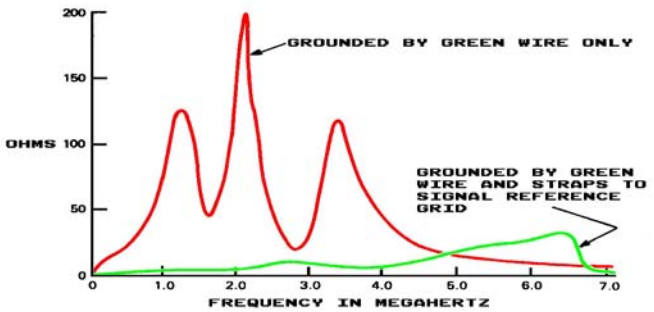
A Tale of Two Towers

- 500MCM conductors added to "improve reference"
- Added grounding adversely affected equipment

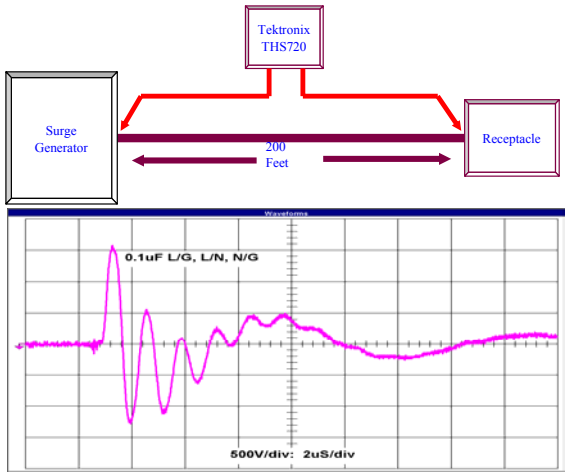


Interference Signals in Equipment Wiring

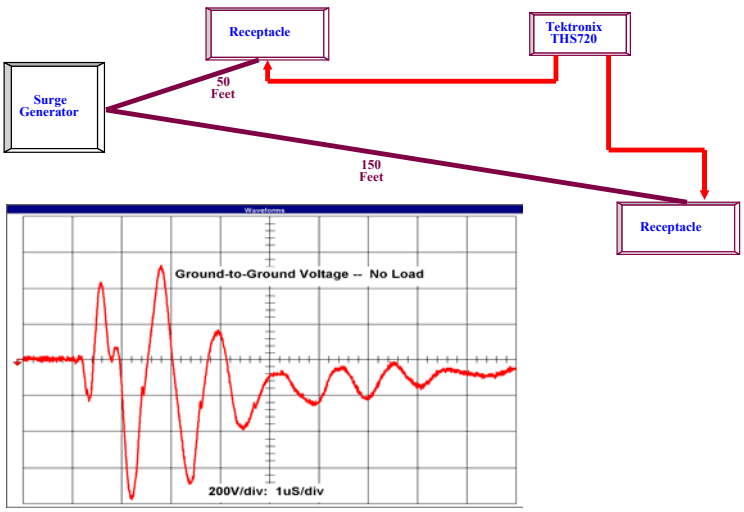
- Federal Information Processing Standards Publication
  - –FIPS PUB 94 -- 1983 September 21 -- Now discontinued
  - –US Department of Commerce - National Bureau of Standards
- Guideline on Electrical Power for ADP Installations



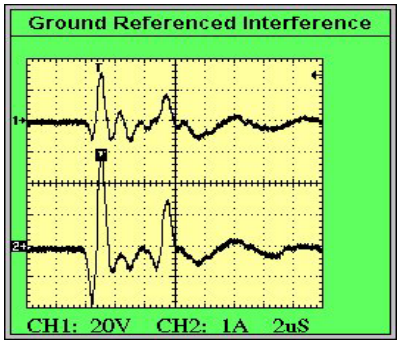
Ground Voltage Rise (200' Romex)

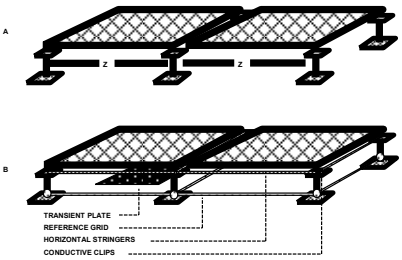


Ground Voltage Differentials



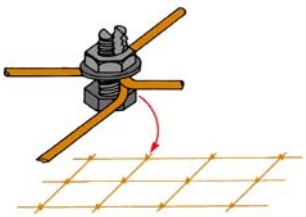
Signal Reference Grid 1

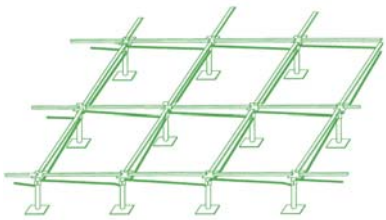




Signal Reference Grid 2

- FIPS PUB 94
  - 4 AWG copper conductors -- clamped intersections
    - Not a bad reference grid
  - 1" metal braid and pedestal clamps
    - A better reference grid





4'x4' Reference Grid

SRG intersection points not bonded together

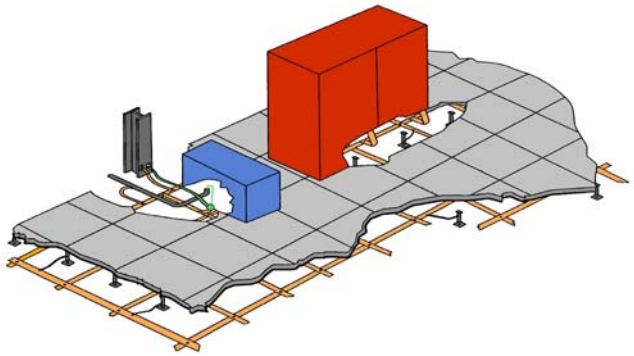
Less effective than would be with good connections.

Connections to Reference Grid

- Short flat straps best
- Metal braid OK
- Bond at opposite corners of equipment
- Bond all equipment within room

Signal Reference Grid

- A very good reference grid



Information Technology Rooms

- Article 645 of NEC
  - –NEC 645-15 Grounding [1999 - 2005]
    - Power systems that supply power through receptacles or cable assemblies supplied as part of the system are not considered as separately derived.
    - Signal reference systems must be bonded to the equipment grounding system provided for the information technology room.
- Recommended References
  - –NFPA 75-1995
    - *Standard for the Protection of Electronic Computer/Data Processing Equipment*
  - –IEEE Std. 1100-1992 -- Emerald Book
    - *IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment*