Grounding Complications

- Sensitive Equipment
- Isolated grounding
- Supplemental grounds

Sensitive Electronic Equipment

- NEC 647 [2002-2005]
  - Originally intended for audio studios – now industrial/commercial applications

- Requirements
  - Separately derived system
  - 2 pole breakers
  - 2.5% & 1.5% feeder/branch circuit voltage drop
  - All 15 & 20 amps circuits must be GFCI protected
  - Ground bus label – Technical Power
  - IG receptacles allowed
  - Three phase applications require the use of 6 phase transformers
Isolated Grounding (IG)

- Isolated grounding receptacles
  - NEC 250-74 Exception No. 4 [1996]
  - NEC 250-146(d) [1999-2005]
- Isolated equipment grounding
  - NEC 250-75 [1996] & NEC 250-96(b) [1999-2005]
- Isolated grounding passing through panelboards
- Grounding must terminate within the derived service

IG vs Regular Receptacle

- IG Receptacle
- Regular Receptacle
IG Application (1)

- IG Normal application -- IG passes back through panels to service origin.
- Grounding wire size must increase to match ampacity of panels it passes through.

IG Application (2)

- IG must terminate at the derived service.
- Stepdown transformer is the derived service, not the main electrical entrance.
IG Position – Reality Check

- Normal distribution wiring spreads incoming signals across many circuits.
- IG circuit extending back to service entrance assures larger signals at "protected" load.

- $V = L\frac{di}{dt}$ -- mutual inductance
- Functions as a 1:1 transformer
- IG use may contribute to "ground loops"

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IG Circuit Induced Voltage

- Chassis voltage and data cable current
- Phase current & induced chassis voltage

IG Ground Referenced Oscillation

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Common IG Error (1)

- NEC violations
  - IG run separately from current carrying conductors
  - IG does not terminate at the derived service

Common IG Error (2)

- NEC violations
  - IG grounding is separate from facility grounding.
  - Supplemental grounding at IG cannot serve as the sole grounding
Isolated Ground Path Problem

- Common mode voltage propagation - Source is equipment leakage current due to an overloaded EMI/RFI power supply filter.
- Effects include lockup, reset & blown serial ports.

Isolated Grounding Effects

- Destructive Common mode voltage
- Voltages develop across I/O circuits
Supplementary Grounding (1)

- **Use is permitted**
  - NEC 250-91(c) [1996] & NEC 250-54 [1999 & 2002]
  - Earth is not an effective grounding means and cannot be the sole grounding means as specified in 250.4(A) and 250.4(B)(4)
  - Supplemental grounding need not meet the electrode grounding provisions of NEC 250.50 or 250.53(C)
  - Equipment must still be effectively grounded

Supplementary Grounding (2)

- Supplementary grounding provides a path for external ground referenced interference to enter a facility
- Avoid use if at all possible
Supplementary Grounding Solutions

- Re-derive & Re-reference
- Bond to facility reference

DC Grounding
DC Grounding Connections

- **NEC 250.162(A) [2005]**
  - Two wire, direct-current systems
  - Operating voltage greater than 50V but less than 300V shall be grounded

- **NEC 250.162(B) [2005]**
  - Three wire, direct-current systems
  - The neutral shall be grounded

- **NEC 250.164 [2005]**
  - Point of connection for direct-current systems
  - Grounding must occur at the first system disconnecting means and not at individual services or at any point of use in the premises wiring

Isolated Vs Contiguous Grounding

- **A = Isolated grounding**
  - DC return grounded independently
  - Voltage differential possible between AC power and dc system

- **B = Contiguous grounding**
  - DC bonded to ac grounding means
  - DC grounding run with ac conductors
Separate DC Grounding Conductor

- DC grounding tied to main facility grounding
- DC grounding conductor run independent of ac conductors
- Attempt to prevent cross-talk between ac and dc conductors

Multiple DC Reference

- Extra dc reference points turns grounding into a dc path
- DC current flows everywhere (inversely proportional to the dc resistance values).
DC Systems and SRG

- Provides an installation consistent with the IEEE Emerald Book

Sources of Unwanted Ground Current
Ground Current Due To Utility Distribution

- Stray Current
- Open Neutral
- Interconnected utility neutral and communications grounding
- Coupling to communications circuits

Stray Current
Utility Transformers

- L/G Primary
- L/L Primary

Ground Current Due to Facility Distribution

- N/G Bonds
- N/G Reversal
- Multiple Neutral cross service of separately derived sources
- Induced Currents
Neutral/Ground Bonds

End User Solution to Ground Loops

- Disconnected N/G bond at power distribution unit
- Violates code
- Safety hazard
- Performance problem
- Certainly not the correct solution to a problem
Neutral and Ground Problems

- Crossed neutrals
- N/G reversal

Grounding Conductors & Current

- Grounded conductor problem
- Induced current due to grounded conductor placement
Tracing Ground Currents

LEAKAGE CURRENTS
COMMON MODE EMISSIONS
LONGITUDINAL GROUND CURRENT

Zero Sum Measurements
Compare Sum & Neutral

Summing Bus Bars
Checking Branch Circuits

N/G bond is the ground fault return point
Current patterns help ID sources

Check Transformers
AC Gaussmeter

- Measures flux density
  - Milligauss & MicroTeslas
- Problems arising from flux density
  - CRT waver
  - Induced current flow in data cables
- Great tool to ID ground loops
  - Easy to use
  - Single axis vs triaxial

Interference & Ground Loop Measurements
Digital Storage Oscilloscope

- Digitizing rate -- 100MS/s & higher
- Bandwidth -- 100MHz & higher
- Vertical resolution -- 8 bit or better
- Single channel triggering
  - Some scopes may have or-gate triggering on multiple channels
- Single ended signal acquisition
  - Differential measurements require multiple channels or external devices.
- Extended monitoring capabilities
  - Metratek software
    - Stores triggered waveforms & rearms scope
    - DFT of acquired waveforms

High Frequency Measurements

- Everything grounded - interference voltages are small - difficult to distinguish from normal equipment operating noise.
- Currents much larger, easier to measure
- Couple using high-frequency transformer
- Digital storage oscilloscope and spectrum analyzer
Conventional Current Transformers

- Fluke, AEMC
- Multiple ranges
  - 1mV/A
  - 10mV/A
  - 100mV/A
- Voltage output versus current output

Rogowski Coils

- Fluke Instruments
- AEMC
- Switch selectable ranges
  - 30, 300, 3000
  - 600, 6000
- Output
  - Voltage signal
Hall Effect Current Probes

- AEMC, Fluke
- May have multiple ranges
- Provides a proportional voltage output for DC currents
- AC currents can also be recorded
- Requires zero adjustment
- Calibration required

Line Decouplers

- Oneac, PowerVAR
- Depending upon model may have
  - L/N low frequency output
  - High frequency L/N and/or N/G output
  - Bandwidth typically from kHz to low MHz
- Isolates scope from measurement point
- Converts single ended input into differential
High Frequency CTs

- Commercial products
- Manufacturers
  - EMCO, Tegam, Fischer Custom Communications, Amplifier Research
- Intended use
  - 50 Ohm interface
  - Scopes & spectrum analyzers
- Range
  - 100kHz to 100MHz
  - 1MHz to 1GHz

Plate Antenna

- Construction
  - Metal top and bottom
  - Plastic sides
  - Probe
    - 10MegOhm ~ 10x
    - Total capacitance 35pF
- Intended use
  - Digital storage scopes
  - Record radiated signals, cable potentials, floor potentials
Commercial Loop Antenna

- Manufacturers
  - EMCO, Antenna Research
- Frequency range
  - depends upon model

Ferrite Rod Antennas

- Construction
  - 6" ferrite rod
  - 100 turns of 24 gauge telephone type wire
  - BNC fitting
- Termination provided by scope
- Frequency range
  - 50/60Hz to low kHz
Conclusion

Grounding Items to Avoid

- Supplementary grounding at equipment
  - Parallel to service entrance grounding
- Conduit killers
  - No grounding wire – loose connections
- Needless IG use
  - Grounding bypass of separately derived source
- Grounding "antennas"
  - Daisy chain grounding wires in workstation clusters
  - Lift or defeat data cable shielding of disconnect pin 7 for RS-232-C
- N/G bond removal at transformers to stop ground loops
- Avoid grounding differentials within facilities
  - Control interference at point of origin
Grounding Do's

- Augment service entrance grounding when needed
  - Match the surroundings
- Ensure grounding at wye-to-wye service transformers
- Ensure grounding for padmount transformers inside facilities
- Use parity grounding for branch circuits
- Integrate facility grounding into a "Grounding electrode system"
- Remember Kirchoff's laws
- Use Faraday concept for facility grounding
- Employ reference grids in raised floor environments

Concluding Statements

- Current Flows in Paths - Kirchoff's Laws Prevail
- Ground is a path - not a terminus - and understanding the paths is the key to good grounding
- Interference can compromise good grounding – if something looks ugly – fix it!
- Electrical Codes cannot be compromised by grounding practices