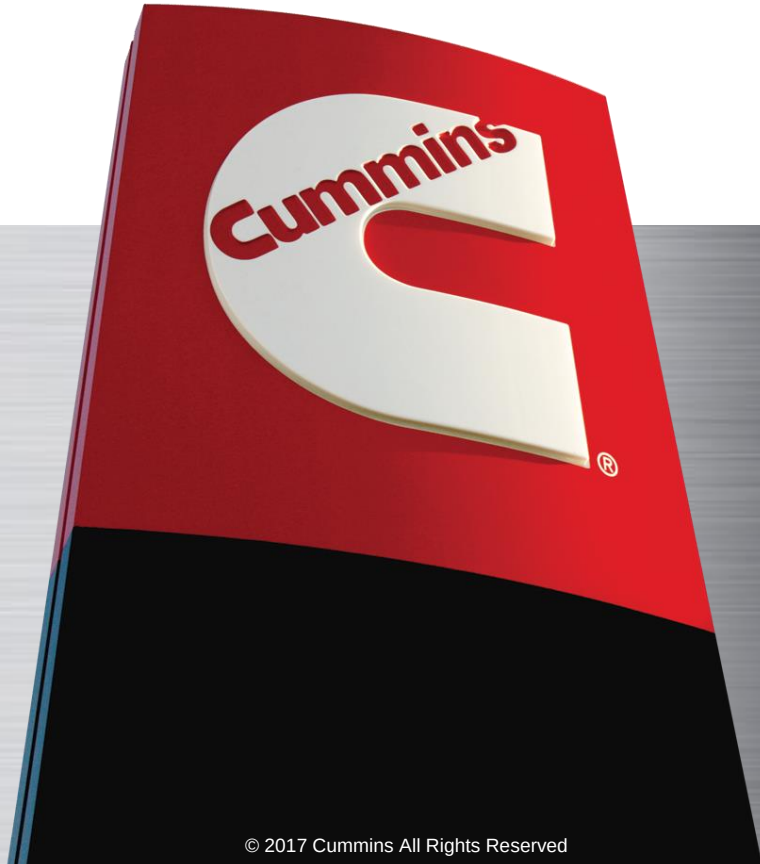
Grounding Recommendations for On Site Power Systems

Revised: February 23, 2017



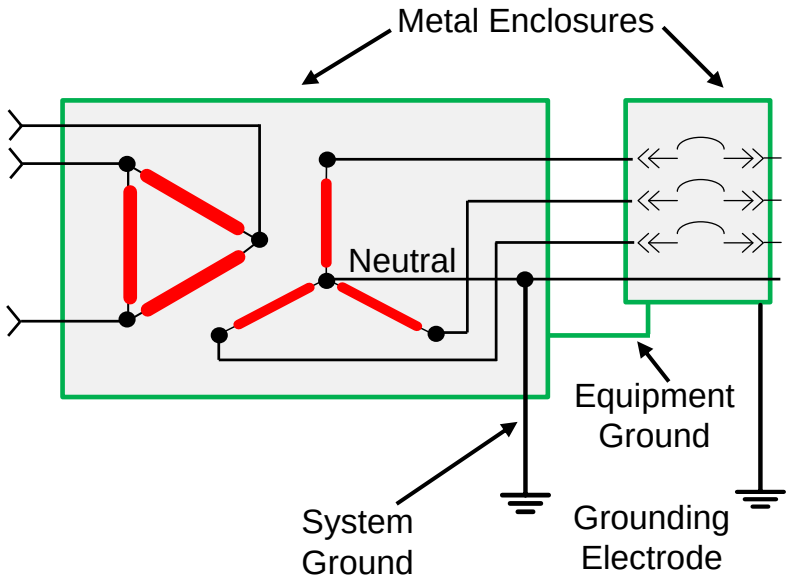
Course Objectives

Participants will be able to:

- Explain grounding best practices and code requirements for system and equipment grounding methods.
- Define requirements for proper ground fault sensing to help design and install ground fault systems that work correctly.
- Define when a 3 pole vs 4 pole transfer switch should be used so that neutral and ground current loops are eliminated and ground fault detection systems work correctly.
- Identify key factors of paralleled systems that need to be considered so that ground fault detection systems will work properly.

Equipment Grounding vs System Grounding

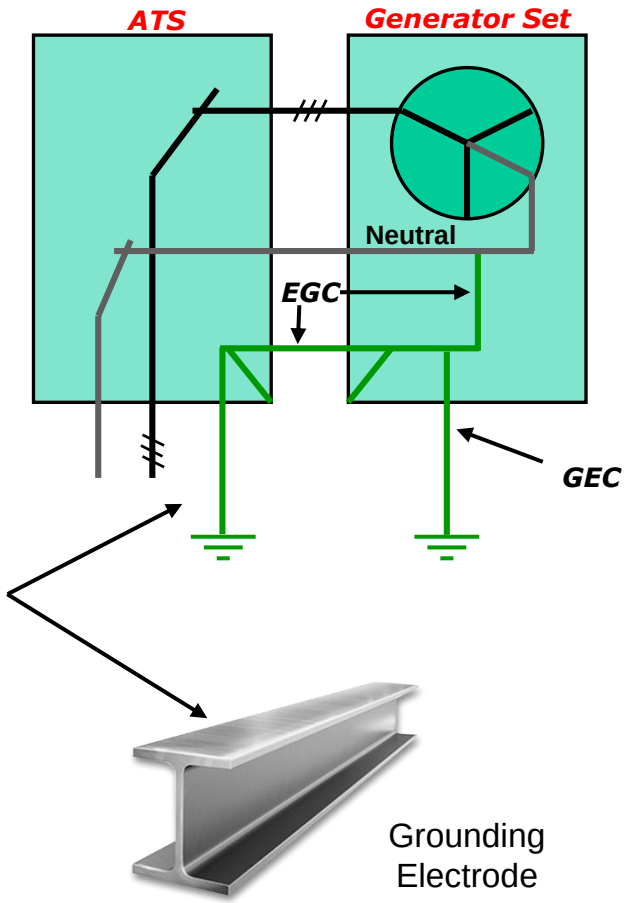
- Equipment grounding
  - Establish (connect) a conductive path between normally non-current carrying metal parts of equipment AND between these parts and the grounding electrode
- System grounding
  - Deliberate connection between a circuit conductor of a power source and ground (earth)
- Both are part of the path for ground fault current to return to the source



Equipment Grounding

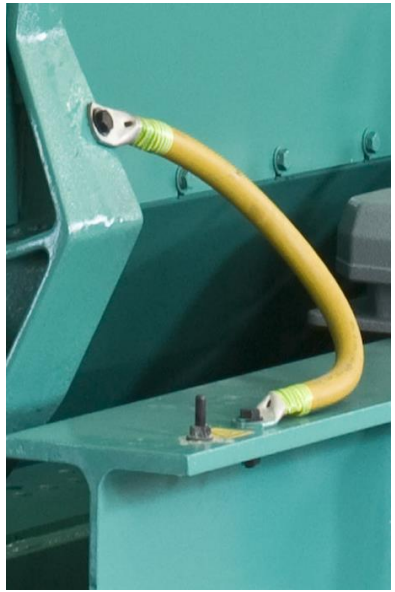
- Equipment Grounding Conductor (EGC)
  - Connects normally non–current-carrying metal parts of equipment together and to the
    - System grounded conductor (neutral) or
    - Grounding electrode conductor (GEC)
  - Provides path for ground fault current

- Grounding electrode: a conducting object through which a direct connection to earth is established such as building steel or a ground rod



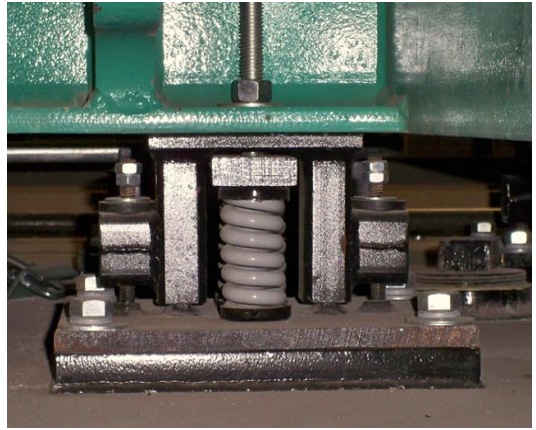
Why Ground Equipment?

- Safety
- Minimizes hazards of touching live equipment
- Minimizes voltages on equipment during fault conditions
- Provide a path for fault current to return to the source
  - Earth is not an acceptable path for fault current to return to the source



Impediments to Effective Equipment Grounding

- Painted surfaces
  - Use ground braid or cable across anti-vibration mounts or painted metal surfaces
- Corroded or damaged ground connections, wires or cables
- Loose ground connections
- Missing star type washers



System Grounding

IEEE Std 142-2007 (Green Book)

System grounding is the intentional connection to ground of a phase or neutral conductor for the purpose of:

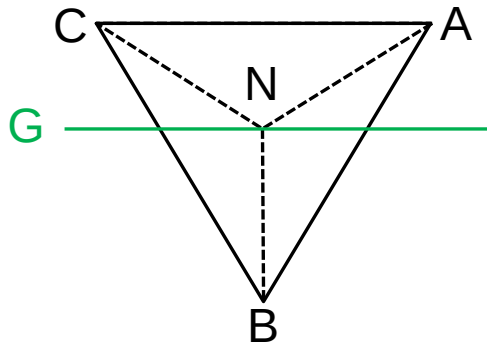
a) Controlling the voltage with respect to earth or ground within predictable limits and

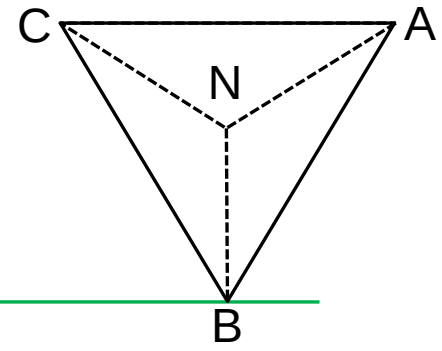
b) Providing for a flow of current that will allow detection of an unwanted connection between system conductors and ground…

… the control of voltage to ground limits the voltage stress on the insulation of conductors…

… the control of voltage also allows reduction of shock hazards

V_{A-G} = 277 V
V_{B-G} = 277 V
V_{C-G} = 277 V
V_{N-G} = 0 V



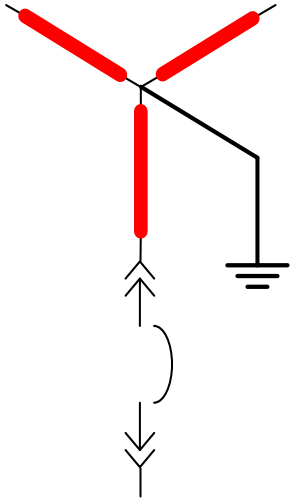


Full Ground Fault on Phase B

V_{A-G} = 480 V
V_{B-G} = 0 V
V_{C-G} = 480 V
V_{N-G} = 277 V

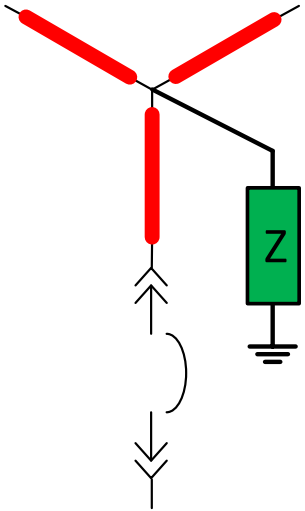
Solidly Grounded System

- Most common grounding method for low voltage generator sets
- Enables ground fault detection and thus activation of ground fault protection equipment
- High level of ground fault current
- Limits excess voltage on ungrounded phases during ground fault



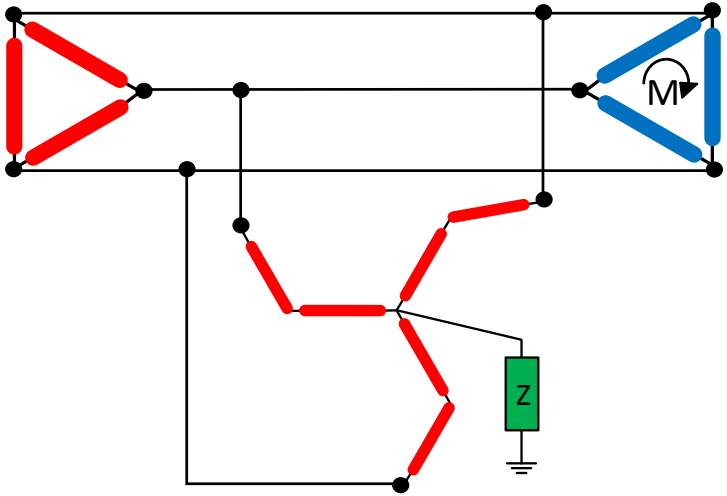
Resistance Grounded System

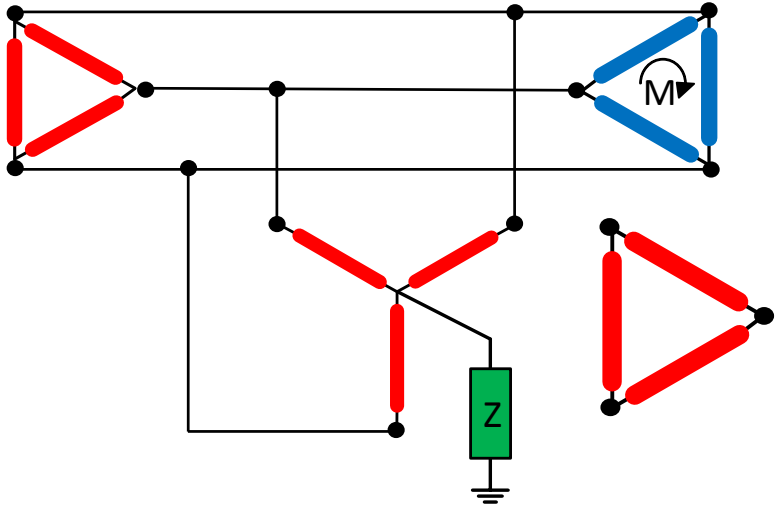
- Commonly used with medium voltage generator sets
- Limits ground fault current level



- Two types of resistance grounded system:
  - Low Resistance Grounding
    - Fault current usually limited to 300-500 amps
    - Easily detectable with conventional CT's
    - Sufficient to trip circuit breakers
  - High Resistance Grounding
    - Fault current usually limited to 5-10 amps
    - Maintain continuity of power during a fault allowing controlled shutdown

Establishing a Neutral on an Ungrounded System

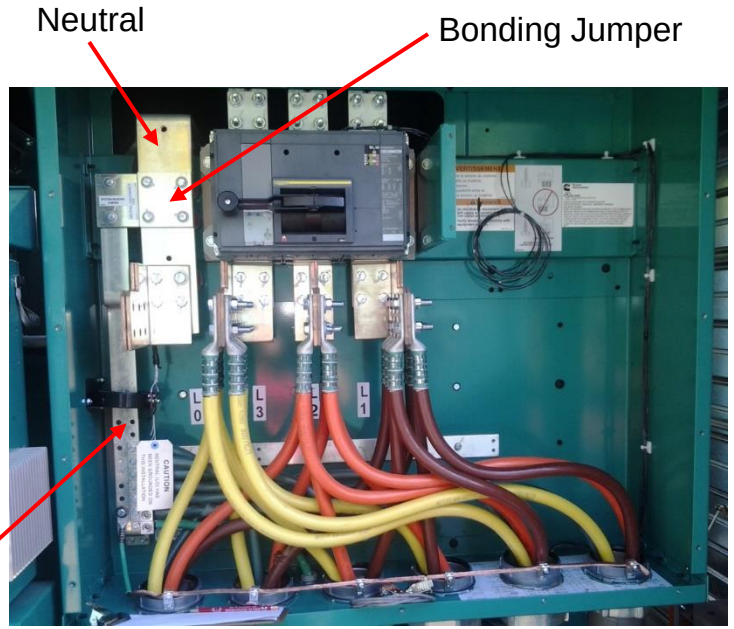




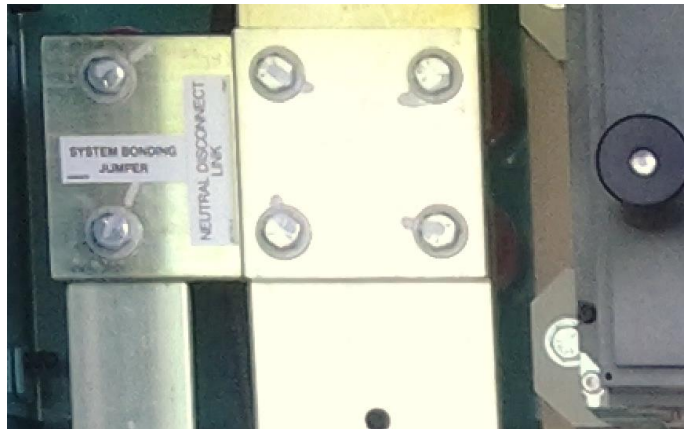
- Zigzag or wye-delta transformers may be used to obtain a neutral for ungrounded systems
- Either solidly grounded or resistance grounded
- High impedance to balanced normal phase currents
- Low impedance to zero sequence (fault) currents

Separately Derived Systems

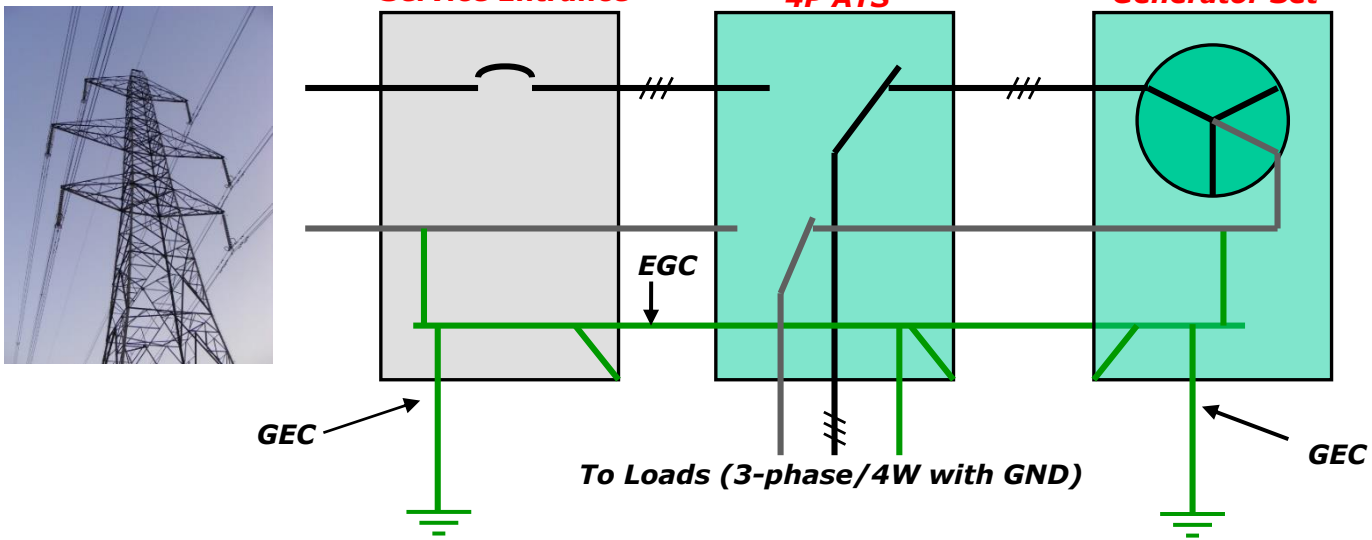
- NEC Definition - “A premises wiring system whose power is derived from a source of electric energy or equipment other than a service. Such systems have no direct electrical connection including a solidly connected grounded circuit conductor, to supply conductors originating in another system.”



- NEC Section 250.30(A)(1) requires separately derived systems to have a system bonding jumper connected between the generator frame and the grounded circuit conductor (neutral)

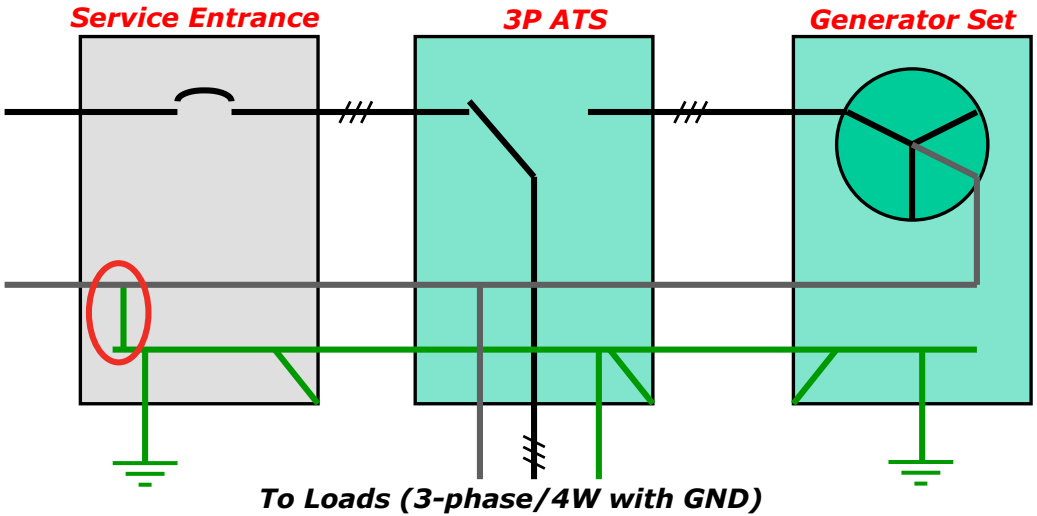


Separately Derived System



- No direct electrical connection between sources
- 3 Phase, 4 Wire System
- 4 Pole Transfer Switch
- Generator neutral is solidly grounded and bonded

Non-Separately Derived System

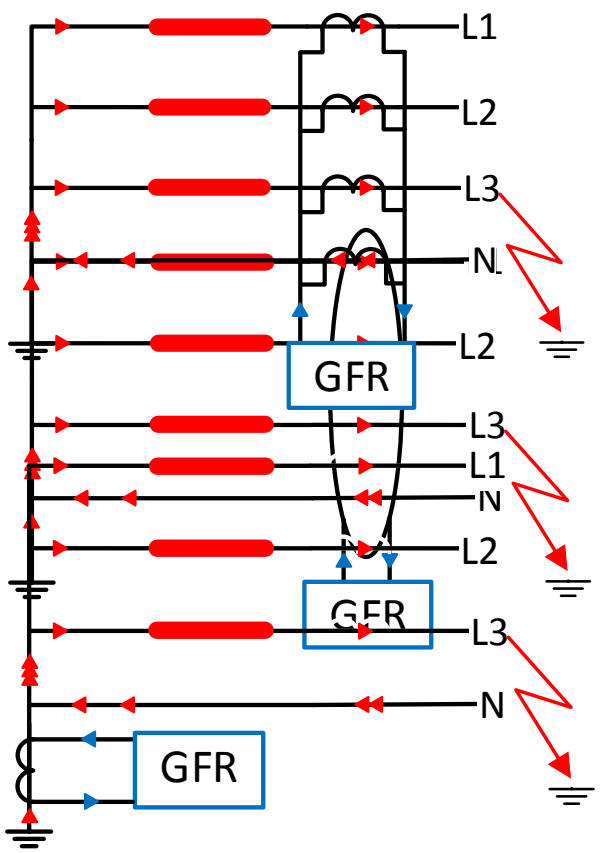


- Common neutral for entire system
- 3-phase, 4 wire system
- 3 Pole Transfer Switch
- Neutral is not grounded at the generator

Ground Fault Protection and Indication

- NEC 230.95 (CEC 14-102) requires Ground Fault Protection (GFP) at the service disconnect (utility breaker) for systems with:
  - Solidly grounded wye
  - More than 150 volts to ground (277/480 or 347/600VAC)
  - Over current device rating of 1000A or More (CEC 120/208VAC & 2000A)
- Ground Fault Indication (GFI), not protection, is required at the emergency source (NEC 700.6 (D))

How Do We Sense Ground Fault?



- Residual
  - Most common method for breakers
  - CTs on each phase and neutral
  - Vector sum of current through all CT's must be 0 (< threshold)
- Zero sequence
  - Single CT around all three phases and neutral
  - Same concept as residual method
- Source ground return
  - Single CT in the neutral to ground bond
  - Method used by our genset control

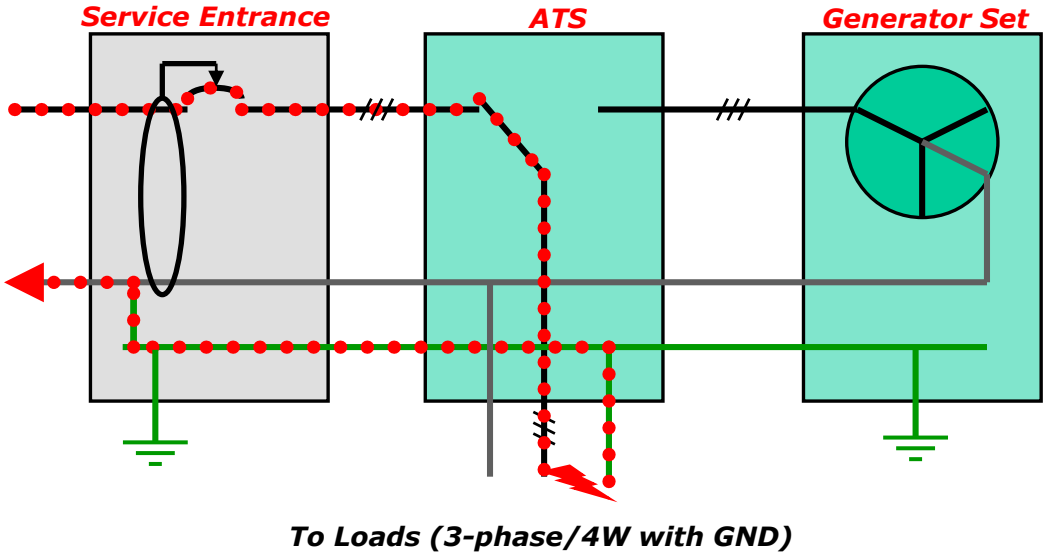
GFR: Ground Fault Relay

Ground Fault Sensing in LV Emergency Standby Systems

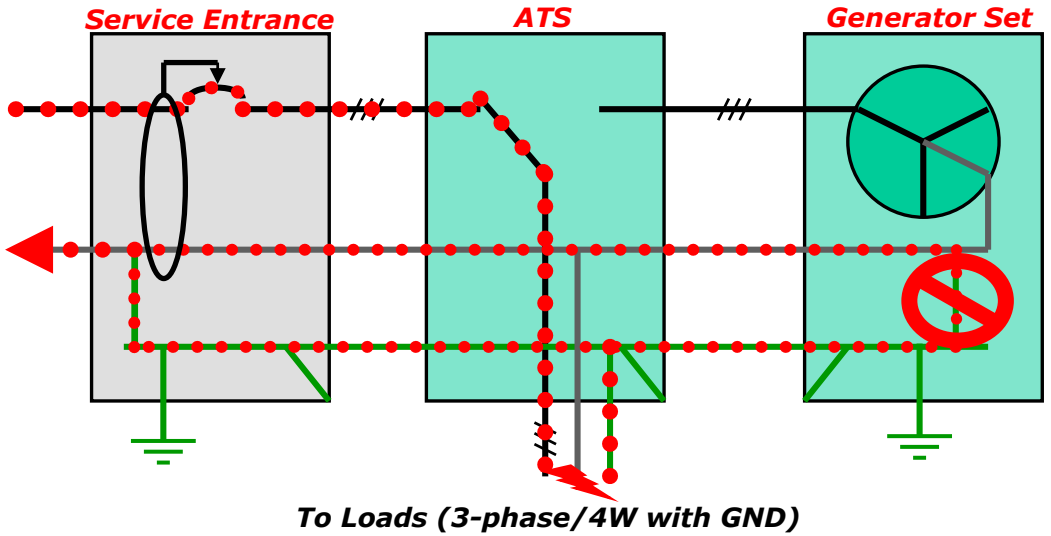
- Most common method is to use GFP in breaker at the service disconnect
- Two rules for proper GF sensing:
  - Rule #1: There must be only one neutral/ground connection on any neutral bus at one time
  - Rule #2: Ground fault sensors must be downstream from the bonding connection
  - These two rules drive the requirement that 4 pole transfer switches must be used when ground fault sensing is required or may be required in the future.

IEEE Std 446-1995 (Orange Book)
7.9.1 “for most emergency and standby power systems with ground-fault systems, switching of the grounded circuit conductor by the transfer switch is the recommended practice.”

Sensing a Ground Fault

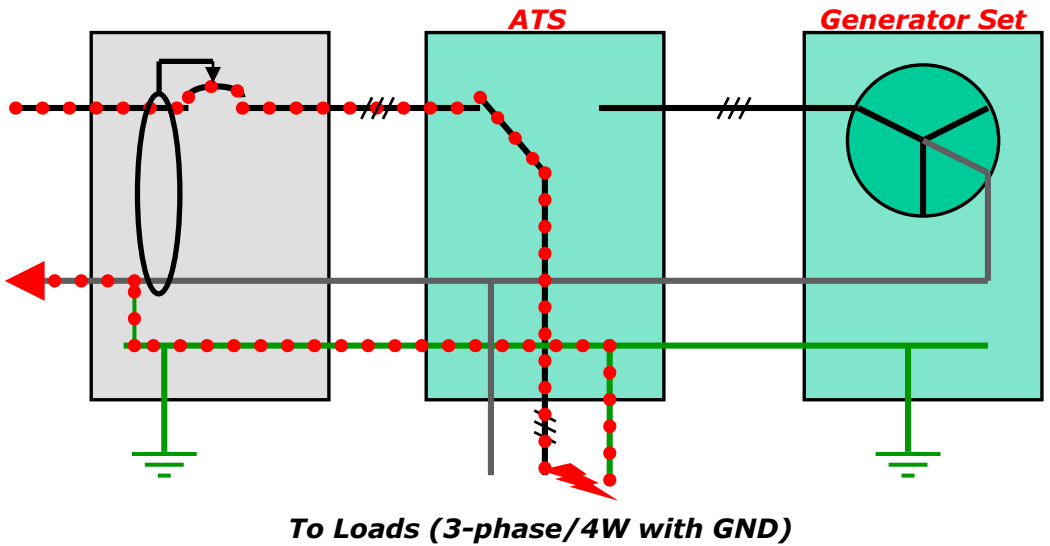


Two Bonding Jumpers



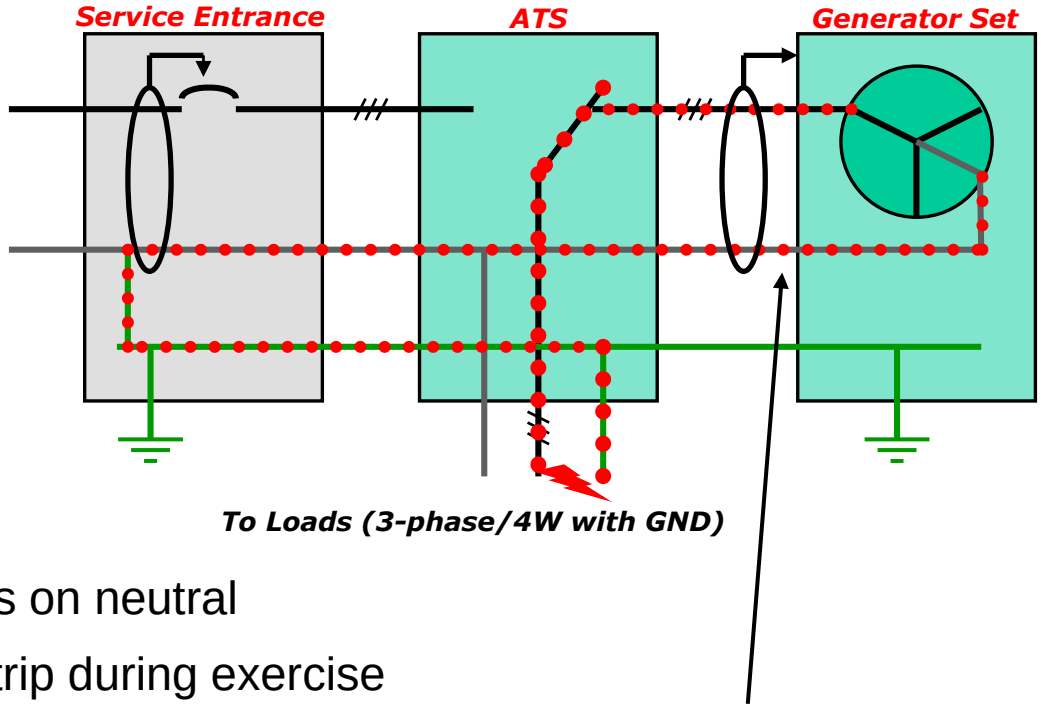
- Parallel path for ground fault current on the neutral
- GFP does not sense all fault current
- Solution: remove the bond on the generator set

Single Bonding Jumper



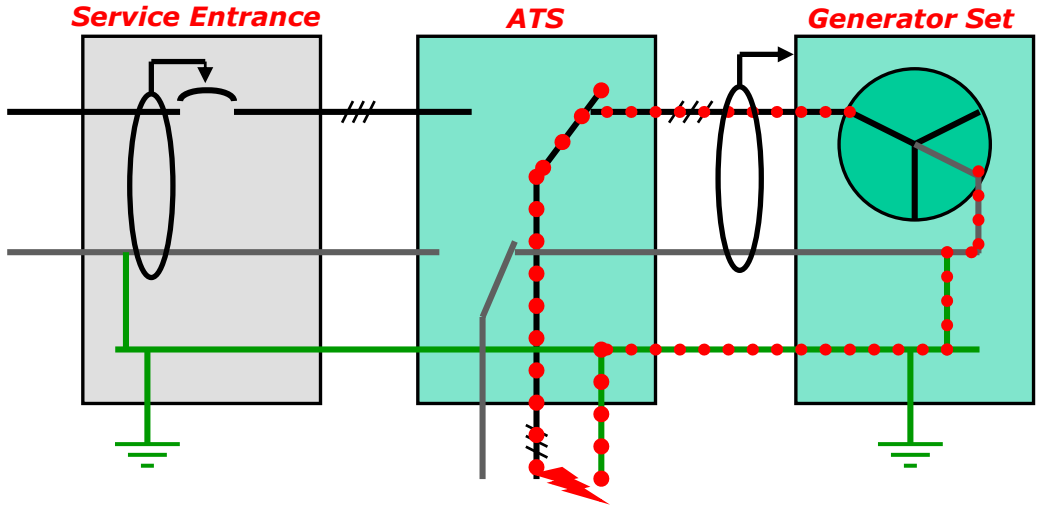
- Removing the generator set neutral bond solves the problem in the previous slide
- There is only one path for earth fault current to return to the source

3-Pole ATS Connected to Emergency Side



- Ground fault returns on neutral
- Possible nuisance trip during exercise
- Solution: ground the neutral on the source side of sensor

Function of 4-Pole Transfer Switches



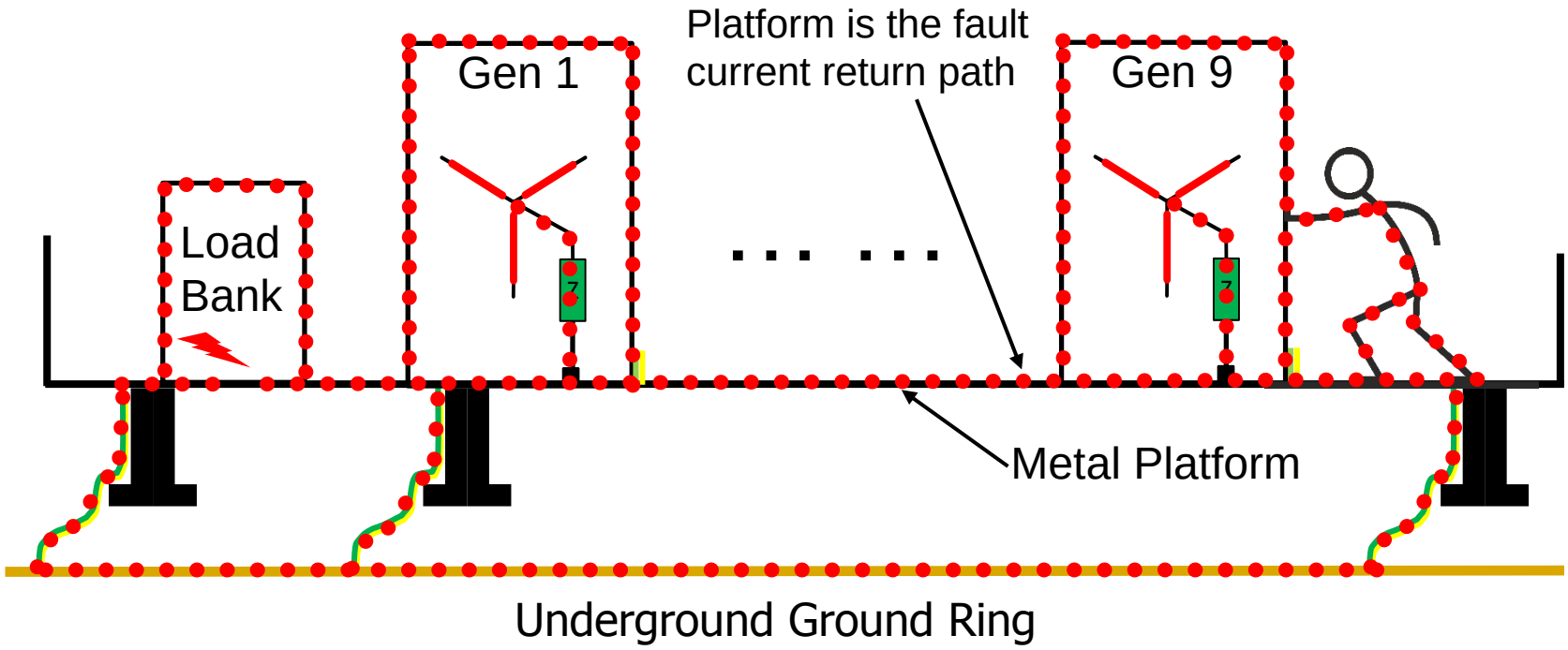
- Fourth pole opens the path on neutral
- Allows accurate GFP sensing on both sides
- The neutral is grounded in only one place at a time
- Ground fault sensor is downstream of the bonding connection

Grounding Case Study

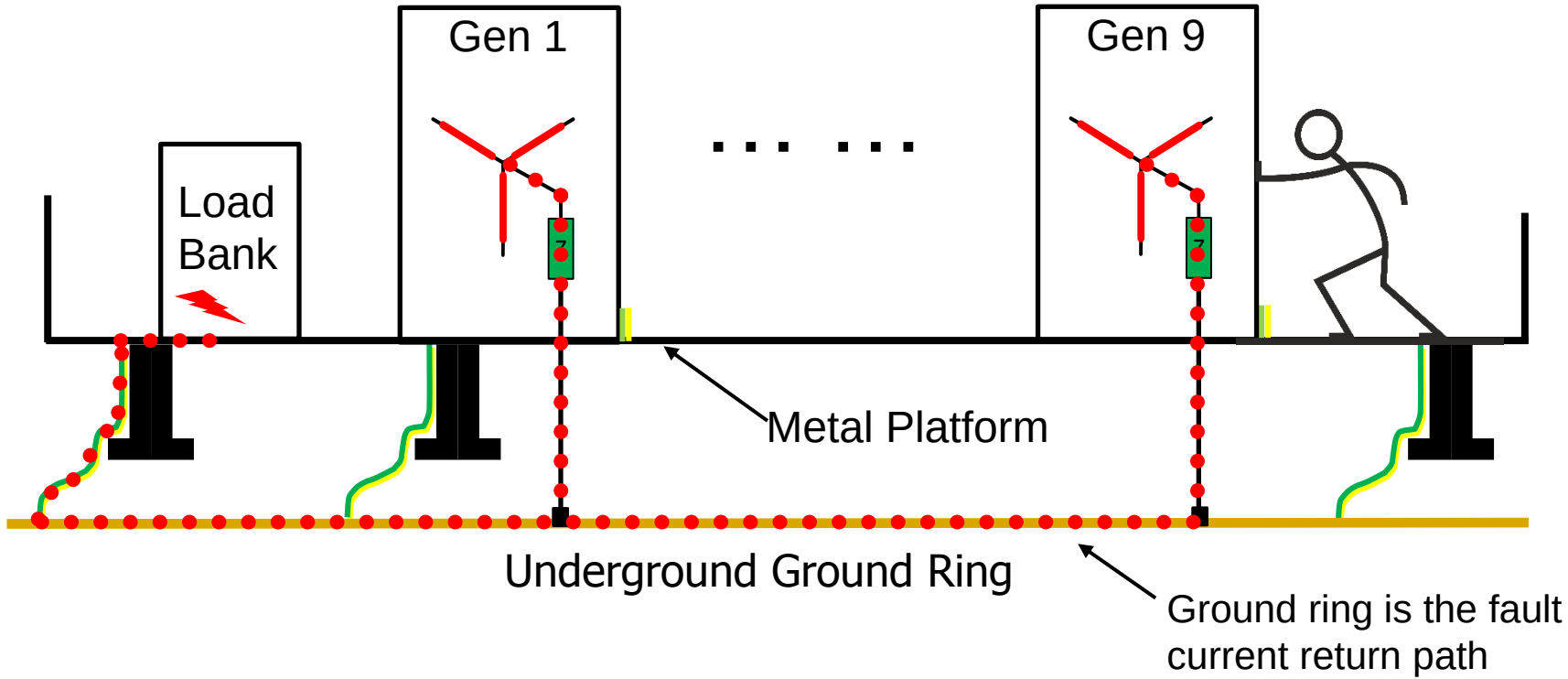
- Nine containerized generator sets on metal platform
- Containers bonded to platform
- Platform connected to underground ground ring
- Each generator is grounded through an NGR located inside the container

Grounding Case Study

- Should the NGR be bonded to the platform? (Yes/No)



Grounding Case Study

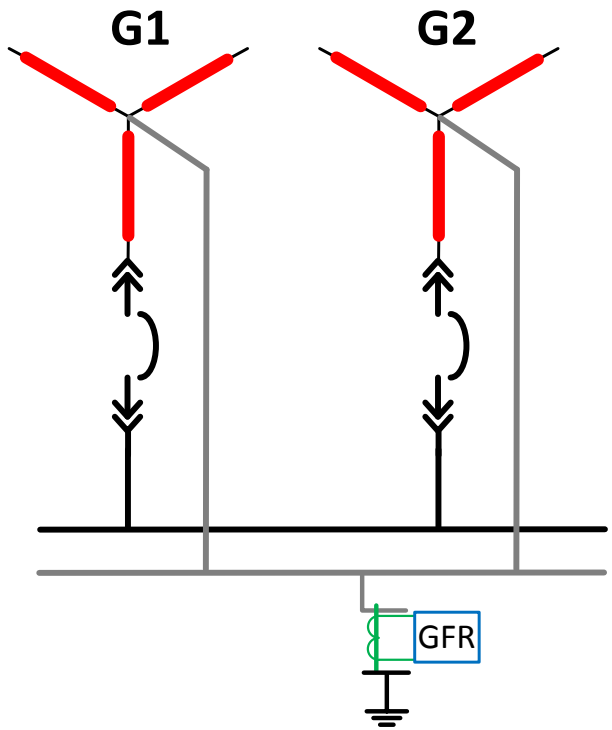


Grounding Case Study

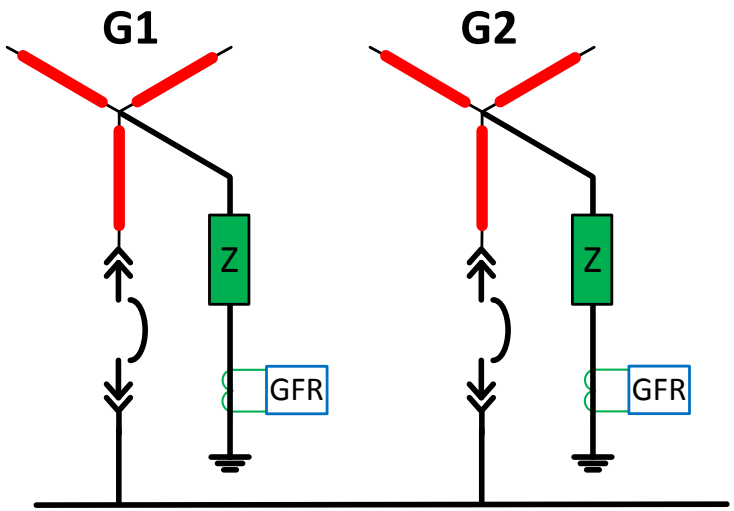
- System ground consists of neutral conductors, NGRs and ground ring
  - System ground is intended to carry current – don't rely on metal structures
- Equipment ground consists of containers, platform, cabinets, etc. and ground ring
  - Ground ring is common to both equipment and system ground

- Establish a low impedance path for fault current to return to the source
  - Path should be through ground ring, not across platform, cabinet, railing
- Minimize touch potential

Grounding of Paralleled Generator Sets

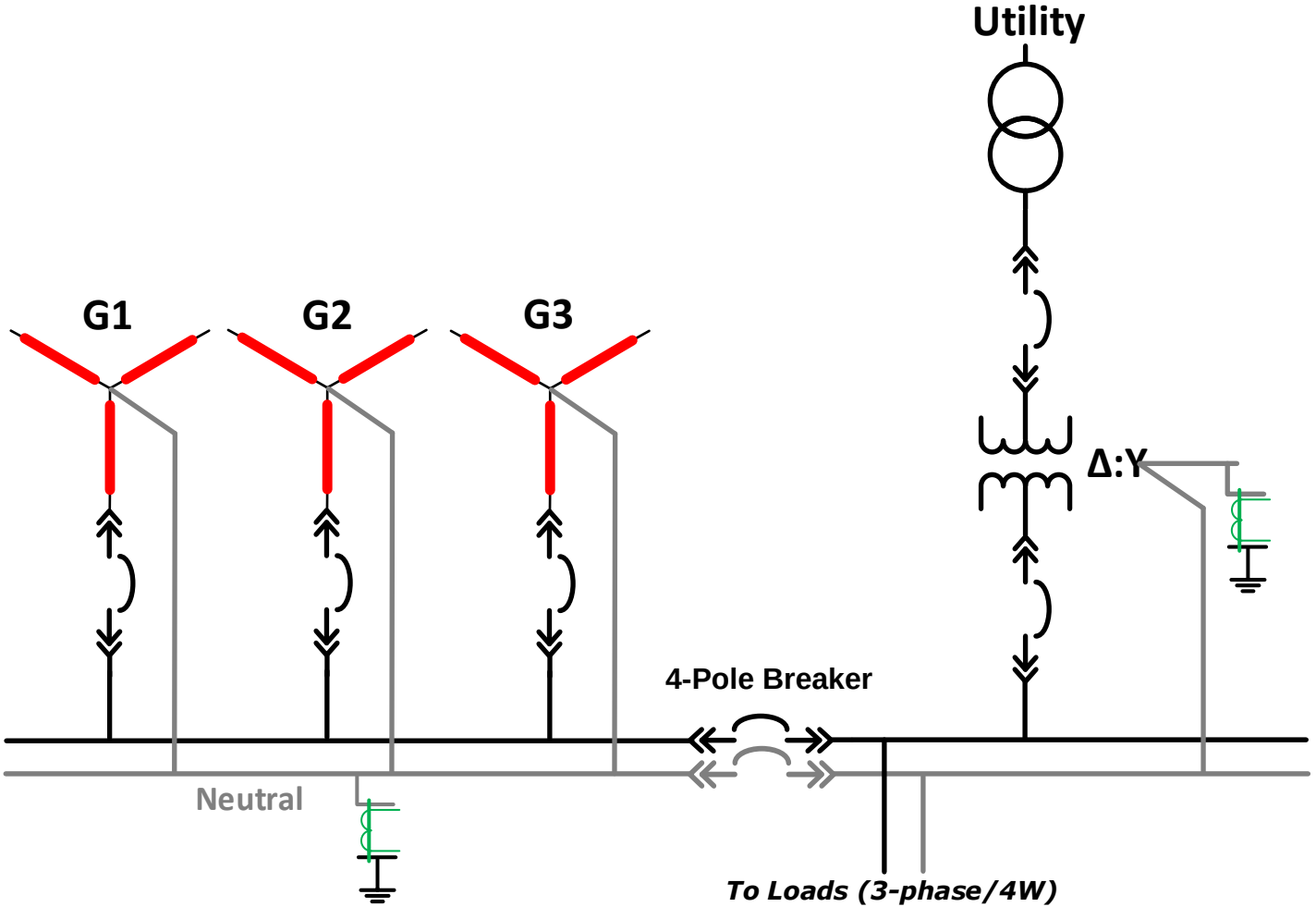


- 4 wire systems typically have a single ground in the switchgear



- Generators in 3 wire systems are typically separately grounded
- Medium or high voltage generators are often resistance grounded

Ground Fault Sensing with Paralleled Systems



Recommendations

- All equipment that can be energized must be grounded
- Ground fault current must have a defined path to return to the sources
- Remember the two big rules for ground fault sensing in emergency standby systems:
  - There can be only one neutral-to-ground bond in the system
  - The sensor for the ground-fault signal devices shall be located downstream of the neutral bonding point
- Specify 4-Pole ATS if:
  - GFP on Normal/GF indication on emergency is required
  - Any 3-phase 4-wire with line-to-ground voltage above150V when future expansion to the facility is expected
- Paralleled sources may require complex ground fault schemes
  - Modified Differential GFP can differentiate between fault current and normal neutral current in systems with multiple sources and grounds
  - Multiple grounds, 4 wire solid neutral systems and utility paralleling applications may require MDGFP

Thank You!

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