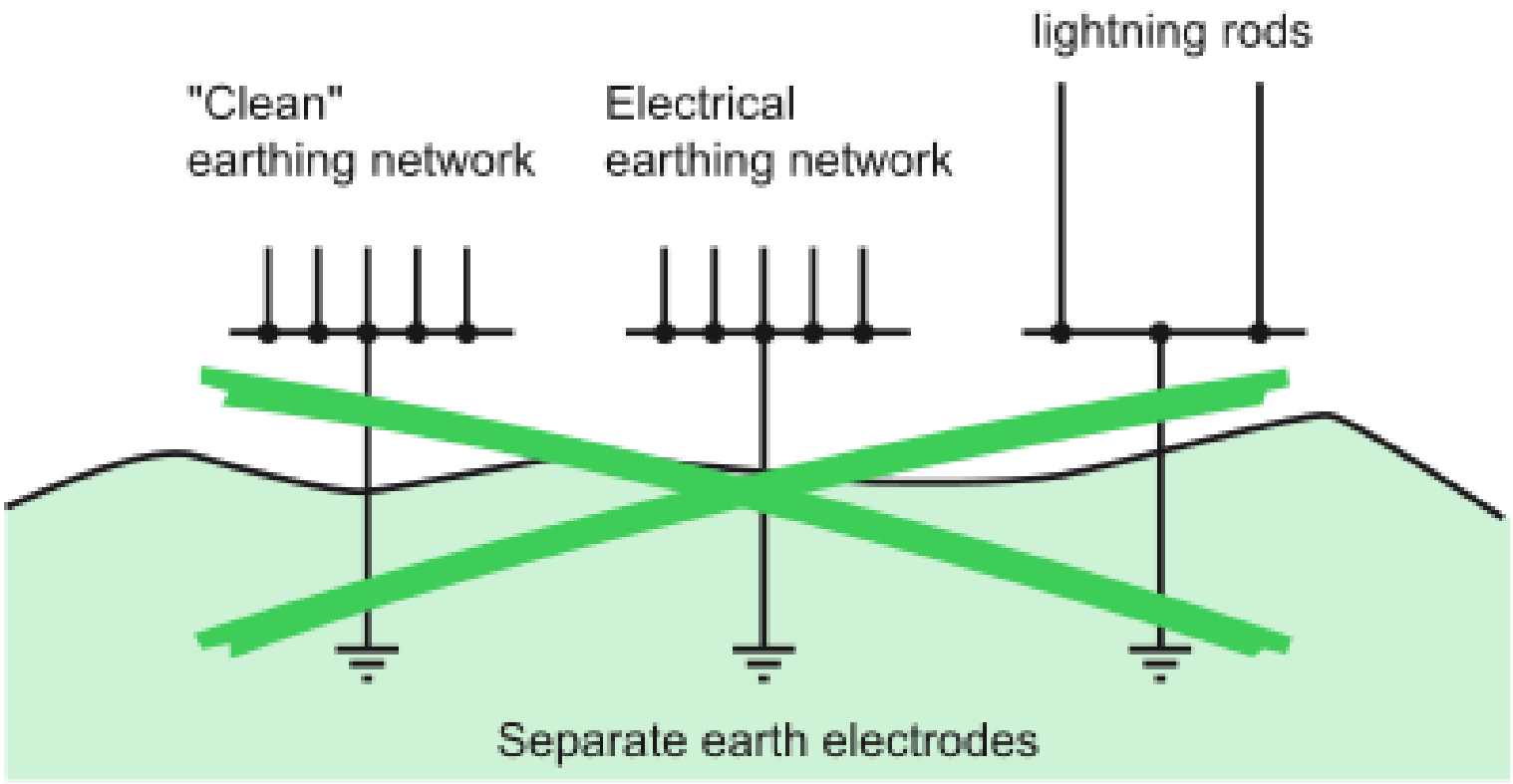


Wiring and Earthing for Power Quality

Cawangan Kejuruteraan Elektrik

WIRING AND EARTHING PERFORMANCE

- The quality of power depends of the quality of wiring system and earthing system in the building.
- Many PQ problems experienced by end users are the result of inadequate wiring (incorrect/improper installations)
- Most of PQ problems show up at the final circuit level where most of the sensitive loads are located.

WIRING AND EARTHING PERFORMANCE

- 75% of PQ problems are related to wiring and earthing problems [1]
- It is more cost effective by correcting wiring and earthing compared to the installation of power conditioners equipment.

MSB, SSB and DB Inspection

Visual and physical inspection –

- The integrity of protective conductors and associated connections.
- The integrity of the earth electrode system.
- Check for an illegal Neutral to earth bond.
- Looks for signs of overheating in busbar or terminal connection (lugs) which cause discolored, which indicate loose connections exist.
- Inspect busbar support insulators and barriers, to ensure free from contamination and also periodically checks for signs of arc tracking.
- Check the size of neutral conductor if the major portion of the load consists of nonlinear loads.
- Check for shared branch neutral circuits.

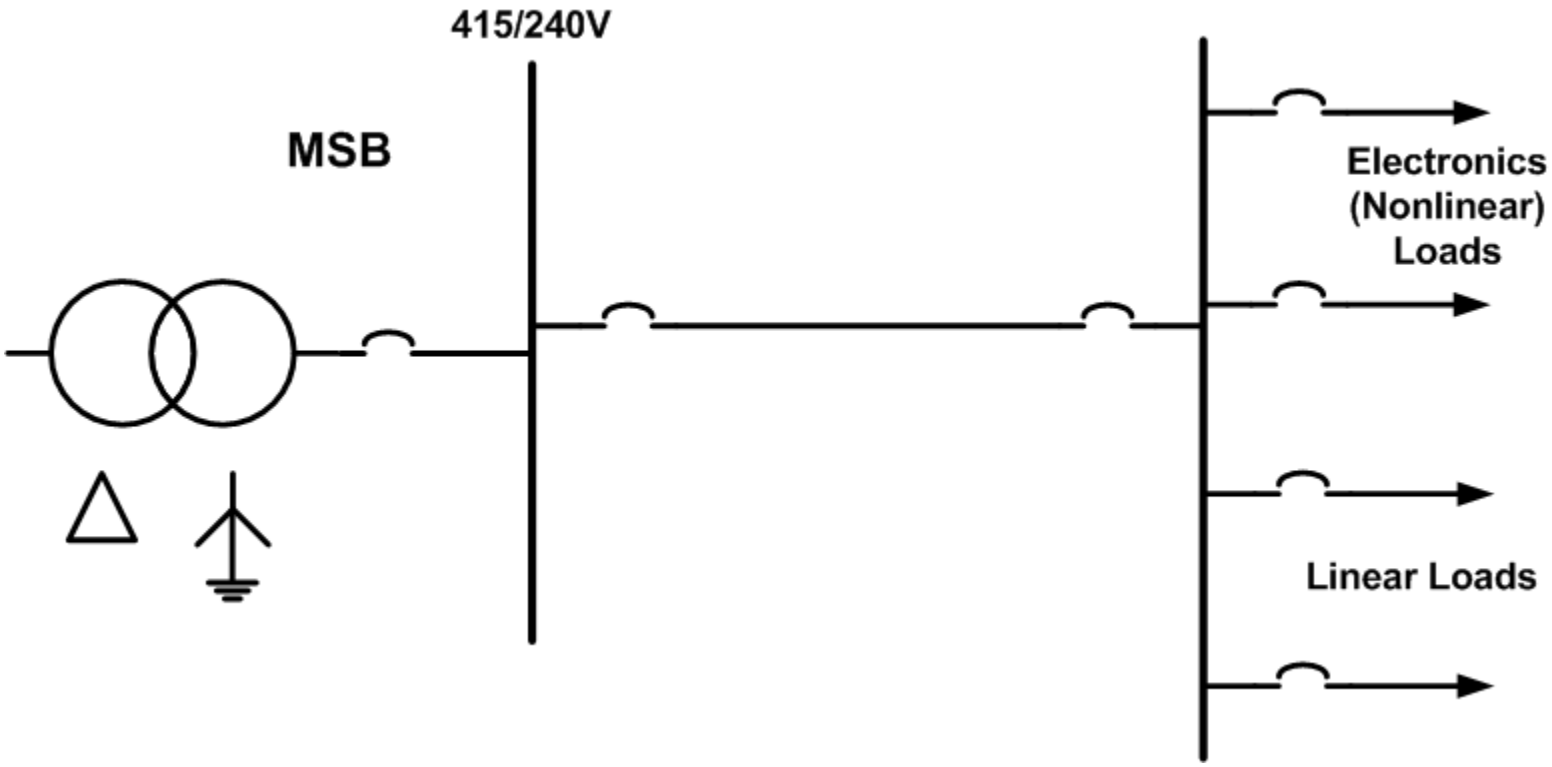
MSB, SSB and DB Measurements

- Phase currents,
- Neutral currents.
- Current flow in CPC (ground loop).
- Neutral to earth voltage at multiple location throughout the system.
- Voltage from the chassis of equipment and the ground (less than 3 volt)
- Phase to neutral voltage.
- Circuit breaker voltage drop.

Proper Wiring Makes A Difference

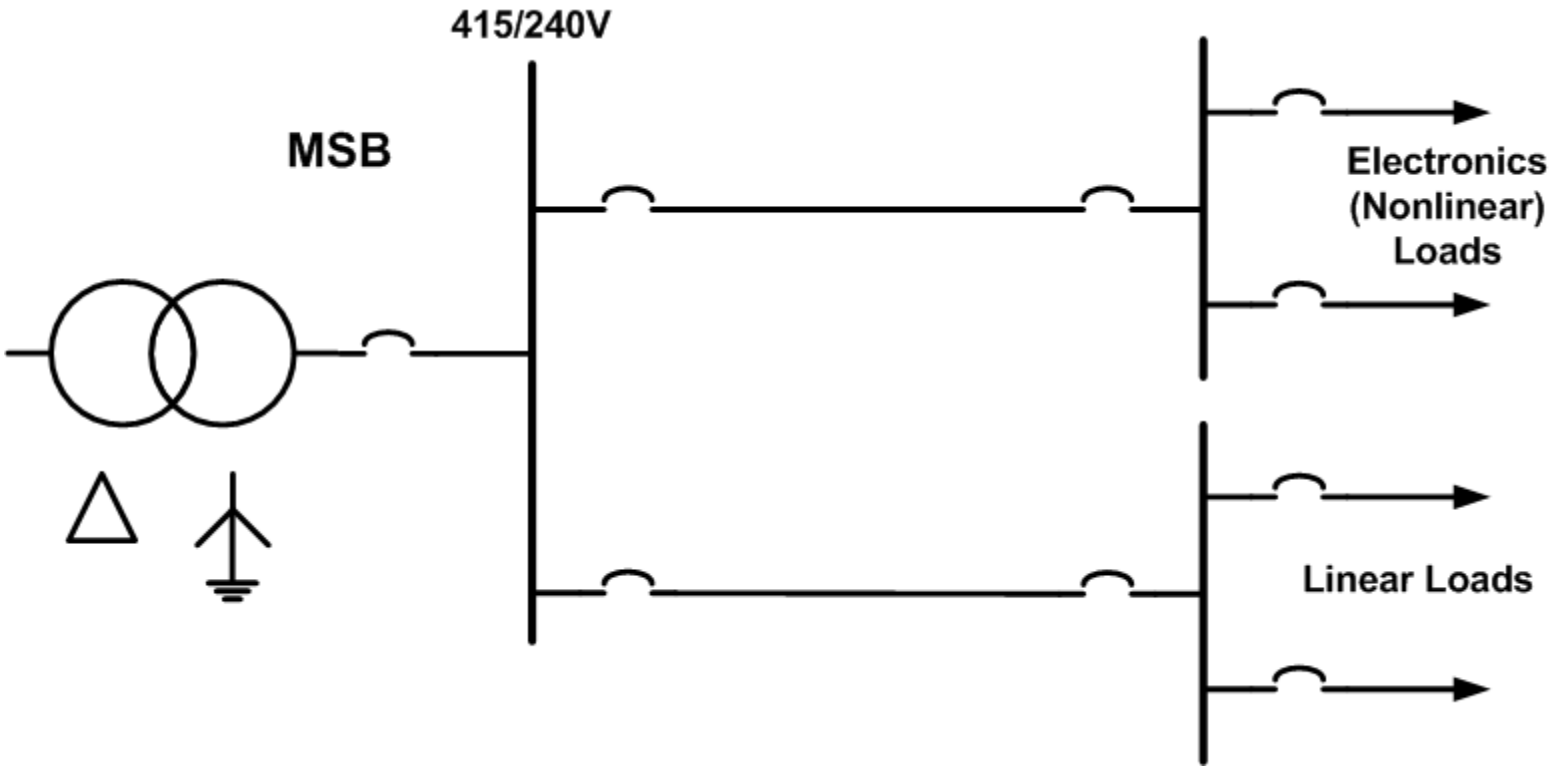
- Run all power and protective conductors together
- Double the size of the neutral or use separate neutral conductors
- Double the size of neutral carrying conductor in the transformer and distribution boards (if applicable)
- Run all telecommunication cables separate from power cables
- Used solid or stranded wire copper conductor for equipment circuit protective conductor, not conduit.

Poor Wiring Installation Design



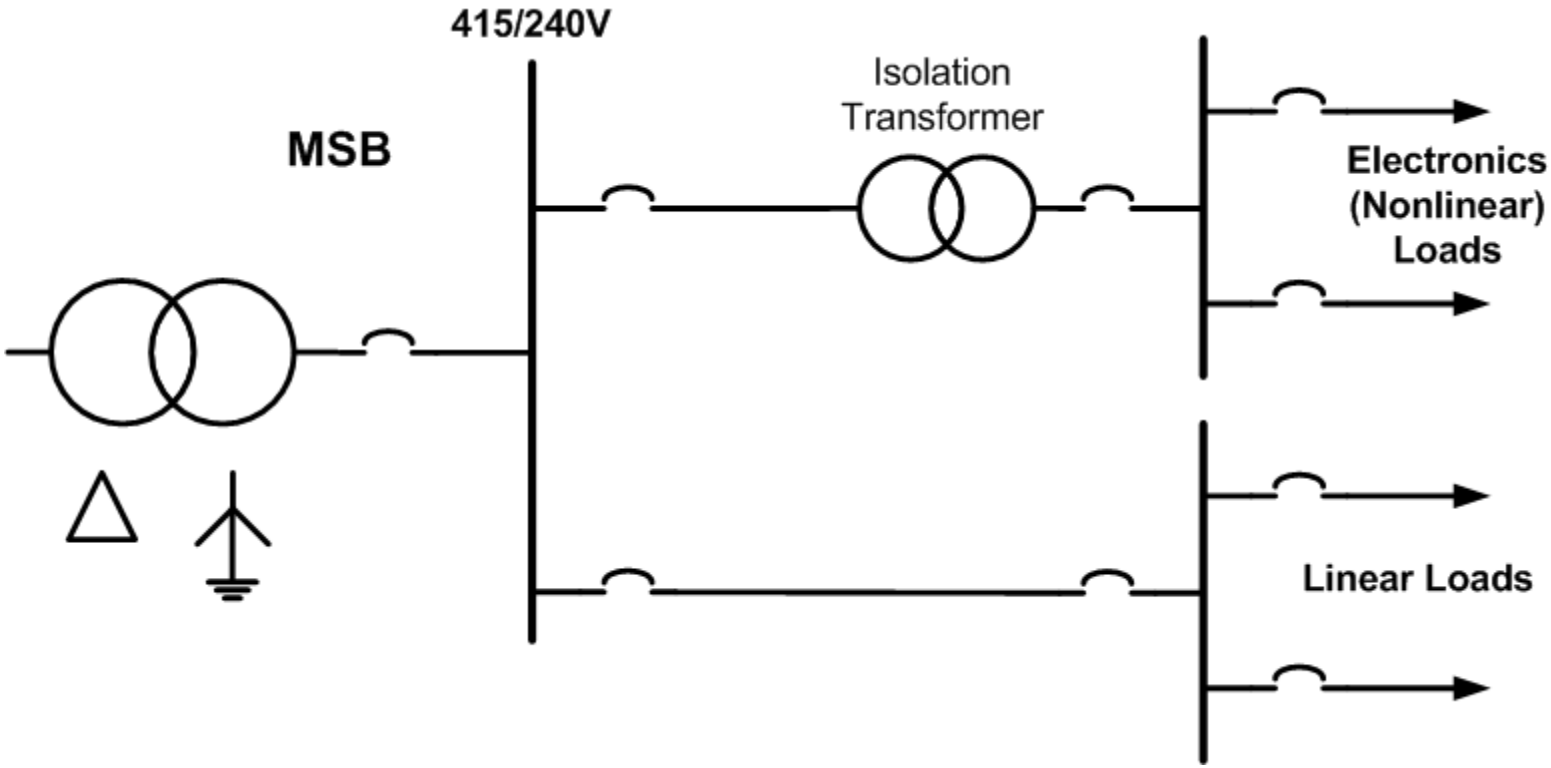
Low Cost, Low Power Quality

Better Wiring Installation Design



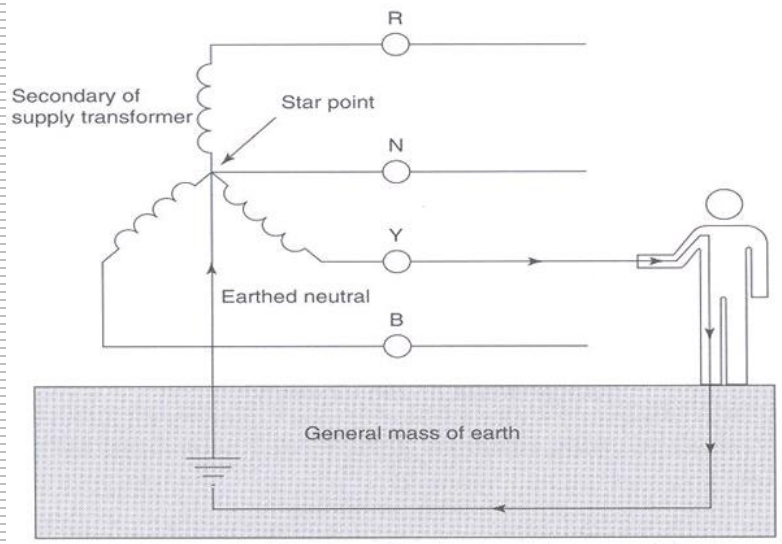
Dedicated Feeds Results in Better Power quality

Best Wiring Installation Design



Dedicated Feeds with Isolation Transformer Results in Better Power Quality

Risk of Electric Shock



- Human are normally in contact with the earth, directly or indirectly.
- If we are in contact with an object that is at potential difference with respect to the earth, electric shock hazard could arise from current flowing through our body with the earth forming part of the closed circuit.

Reasons For Earthing

- Limit Voltage (step and touch potentials) due to, Lightning surges, Line Surges or Contact With Higher Voltage Line
- Provide a low-impedance earth fault current return path.
- Provide a low-impedance leakage current path for any static discharge that accumulate on equipment.
- Facilitate RCD Operation During Fault
- Stabilize Voltage to ground
- Minimize noise interferences in electronic, control & instrumentation

Effective Earthing

- Ground Path Must Be:
  - Permanent and Continuous
  - Ample Current Capacity (during fault)
  - Low Impedance to Facilitate Operation of Overcurrent Devices During Ground Fault

IEC vs IEEE Terms

IEC	IEEE
• Power Distribution System	• Transmission, distribution and Utilization
• Earthed	• Grounded
• Un-Earthed	• Un-Grounded
• Isolation (I)	• Isolated
• Terra (T) meaning earth	• Ground
• Protective Earth Neutral (PEN)	• Grounded Neutral
• Protective Earth	• Grounding

IEC Earthing System

Three basic type of earthing system:

1. TN-System
2. TT-System
3. IT-System

IEC Earthing System Term

- T – ‘Terra’ means direct contact to earth (neutral of the transformer winding).
- I – Insulation of all parts from earth or bonding of one point of the current source to earth via an impedance.
- T (second letter) – Exposed conductive part are directly earthed.
- N – Connection of a conductor to the star or neutral point of the supply transformer.
- C – Neutral and protective conductor are combined.
- S - Neutral and protective conductor are separate.

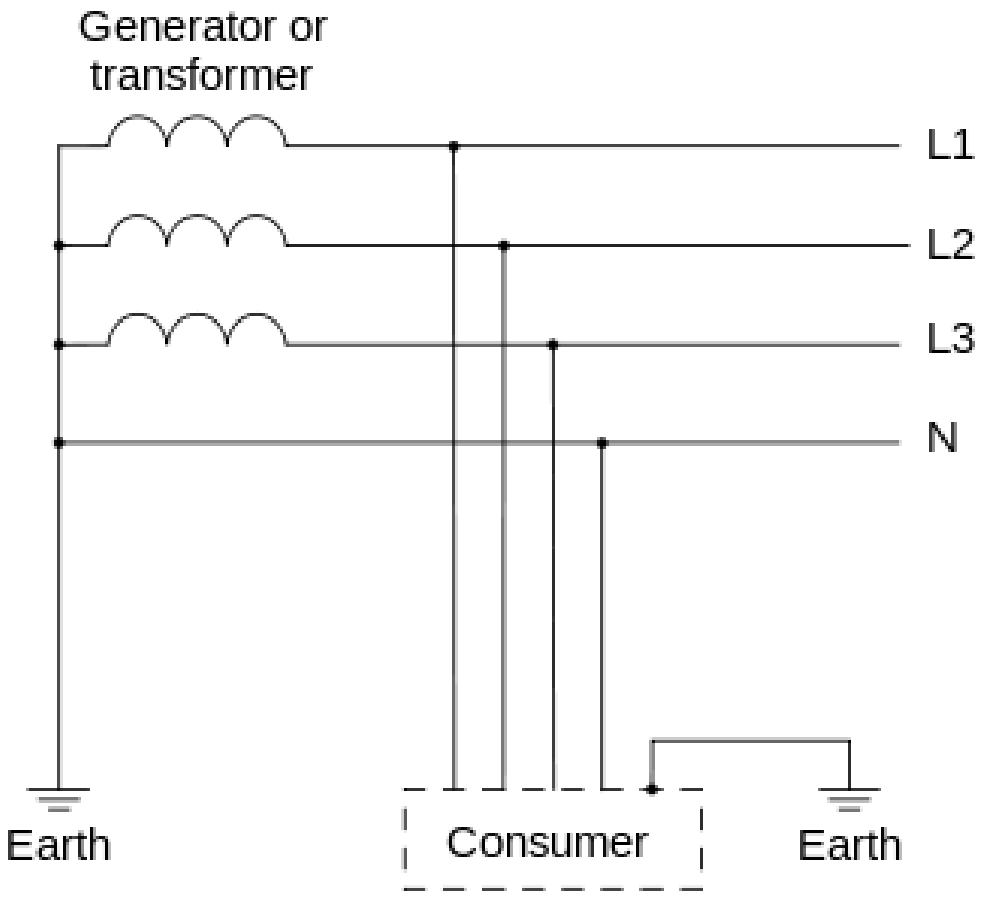
Comparison

	TT	IT	TN-S	TN-C	TN-C-S
Earth fault loop impedance	High	Highest	Low	Low	Low
RCD required?	Yes	No	Optional	No	Optional
Need earth electrode at consumer?	Yes	Yes	No	No	Optional
CPC conductor cost	Low	Low	Highest	Least	High
Safety	Safe	Less Safe	Safest	Least Safe	Safe
Electromagnetic interference	Least	Least	Low	High	Low

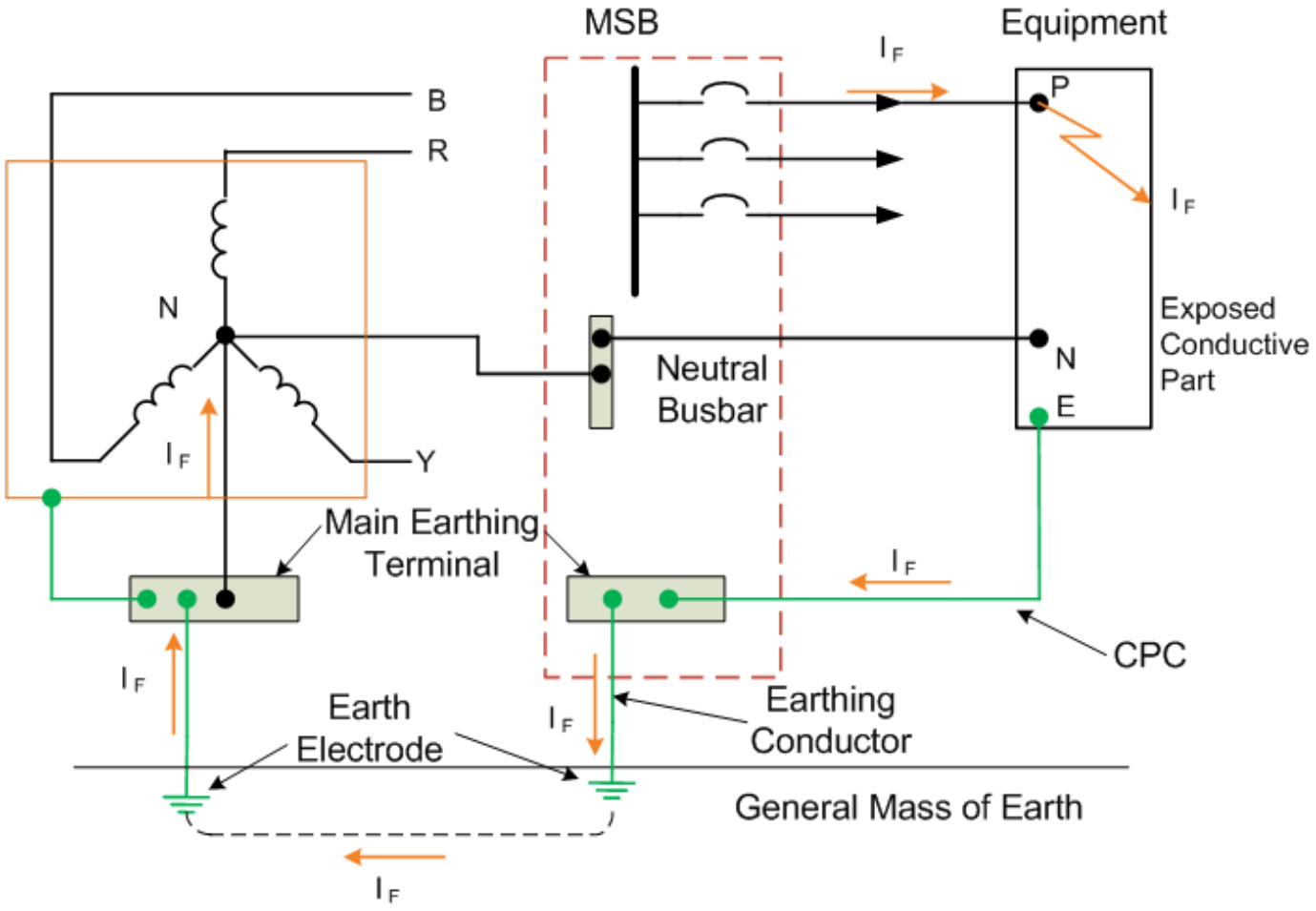
Least, Less, Low, High, Highest

IEC TT System

The supply is earthed via a separate electrode which is independent of the supply electrode.

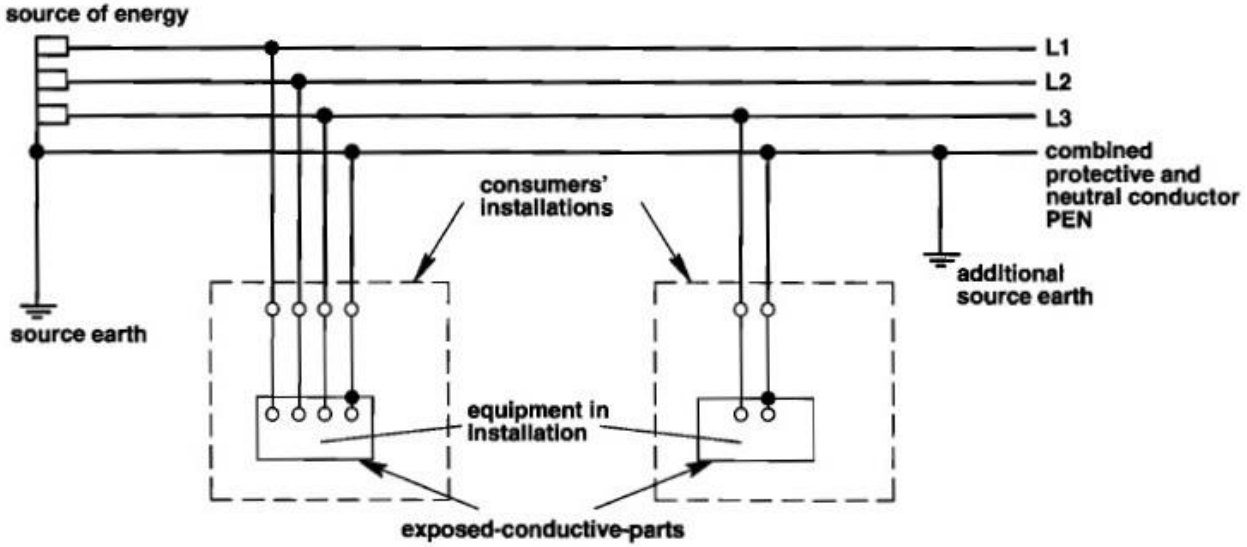


TT-System


MSB
Equipment
I_F
B
R
N
P
I_F
Exposed
Conductive
Part
Neutral
Busbar
N
E
I_F
Y
Main Earthing
Terminal
I_F
CPC
I_F
Earth
Electrode
I_F
Earthing
Conductor
General Mass of Earth
I_F

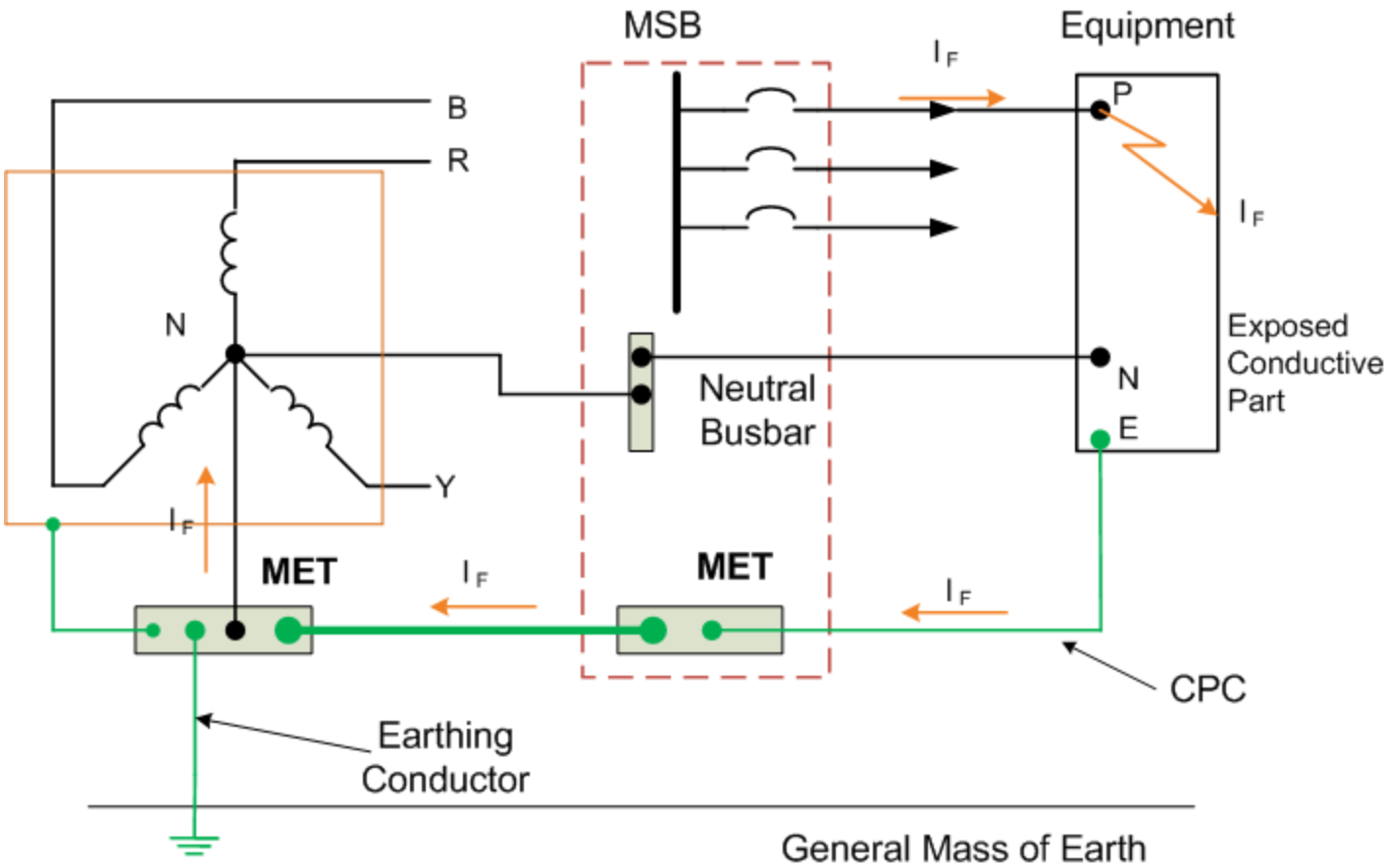
IEC TN-S System

- The incoming supply has a single point of connection between the supply neutral and earth at the supply transformer.
- The supply cables have separate neutral and earth protective conductors



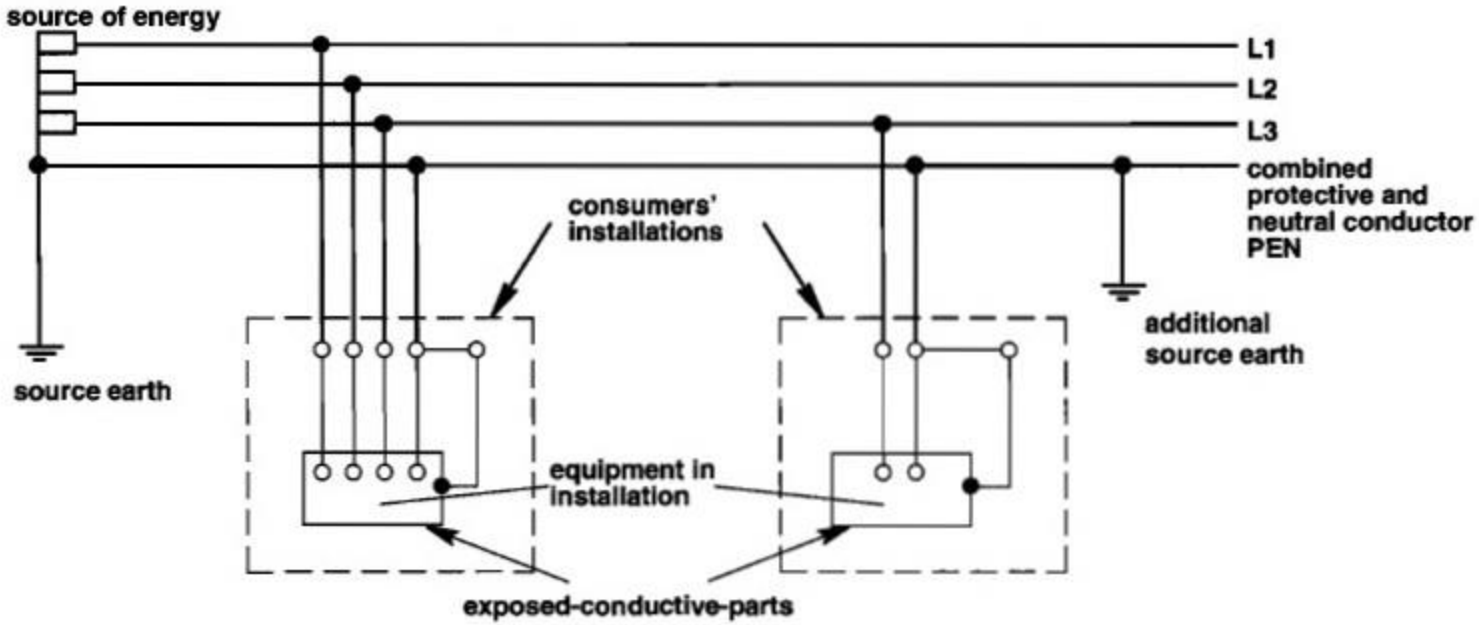
Neutral and protective functions combined in a single conductor throughout system.

TN-S Distribution System



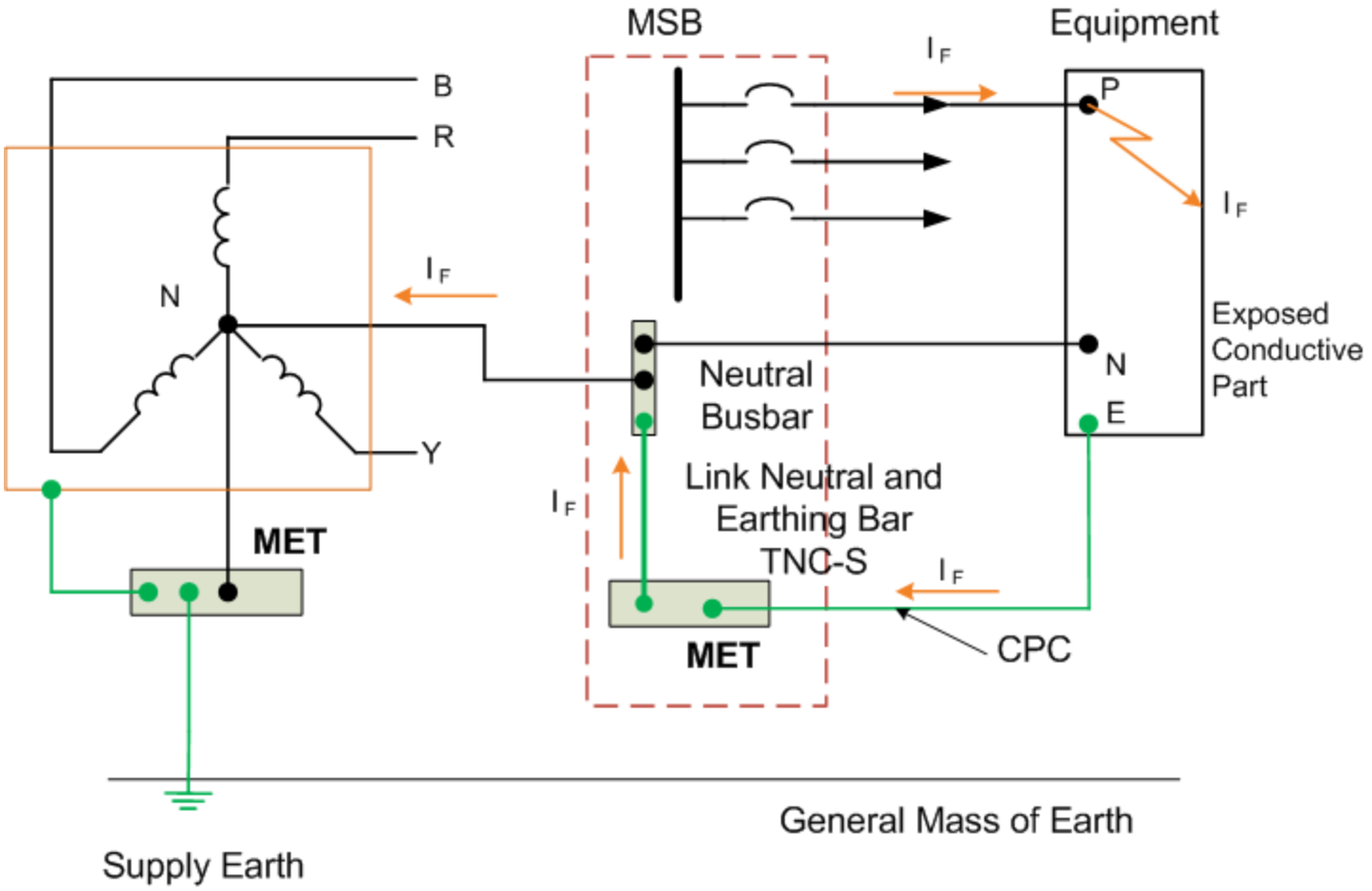
IEC TN-C-S System

- The supply neutral is earthed at a number of points.
- The combined neutral earth sheath is the PEN (protective earth neutral) conductor
- The neutral and earth would be separate, linked only at the service position

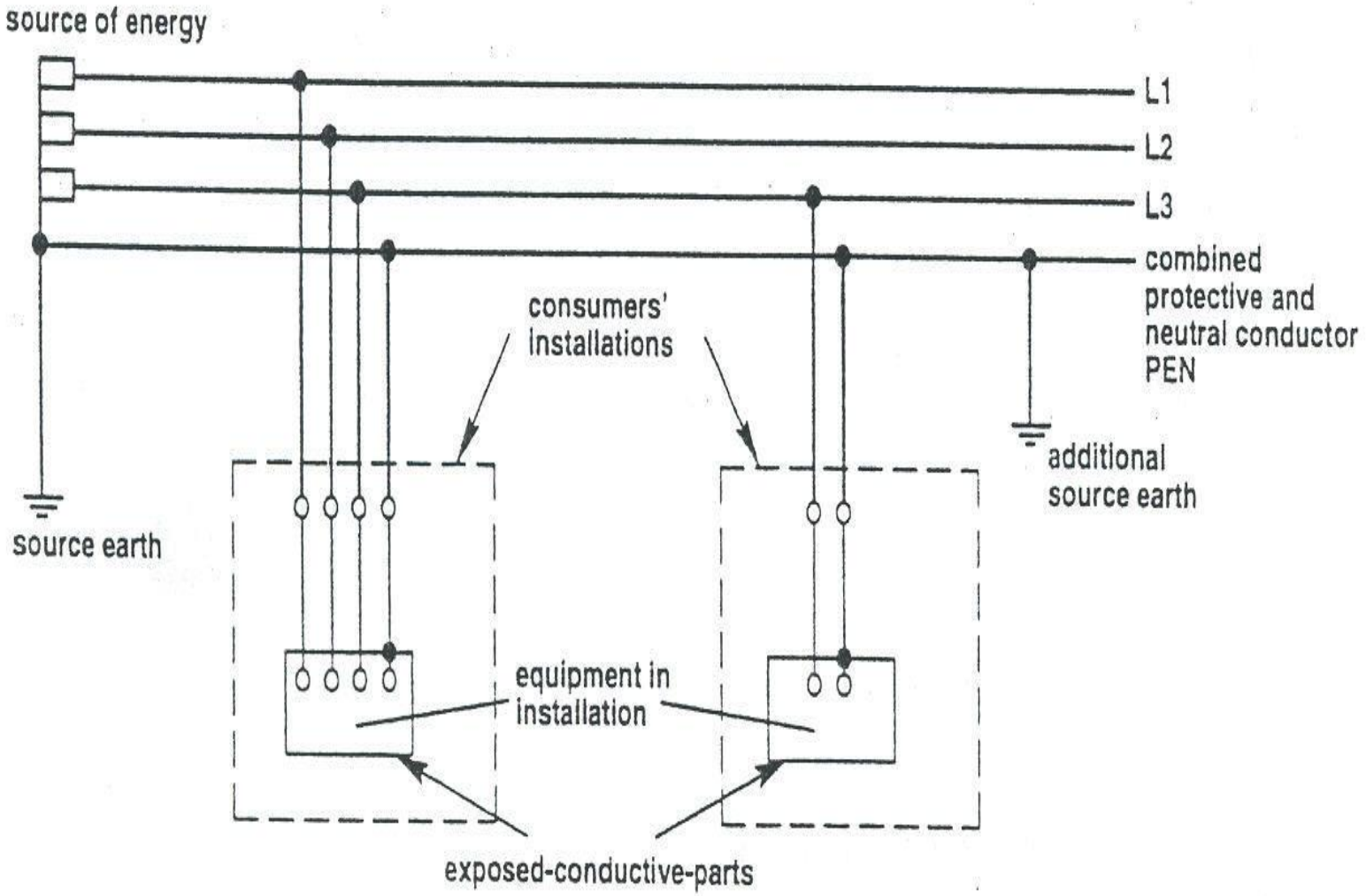


Neutral and protective functions combined in a single conductor in a part of the system.

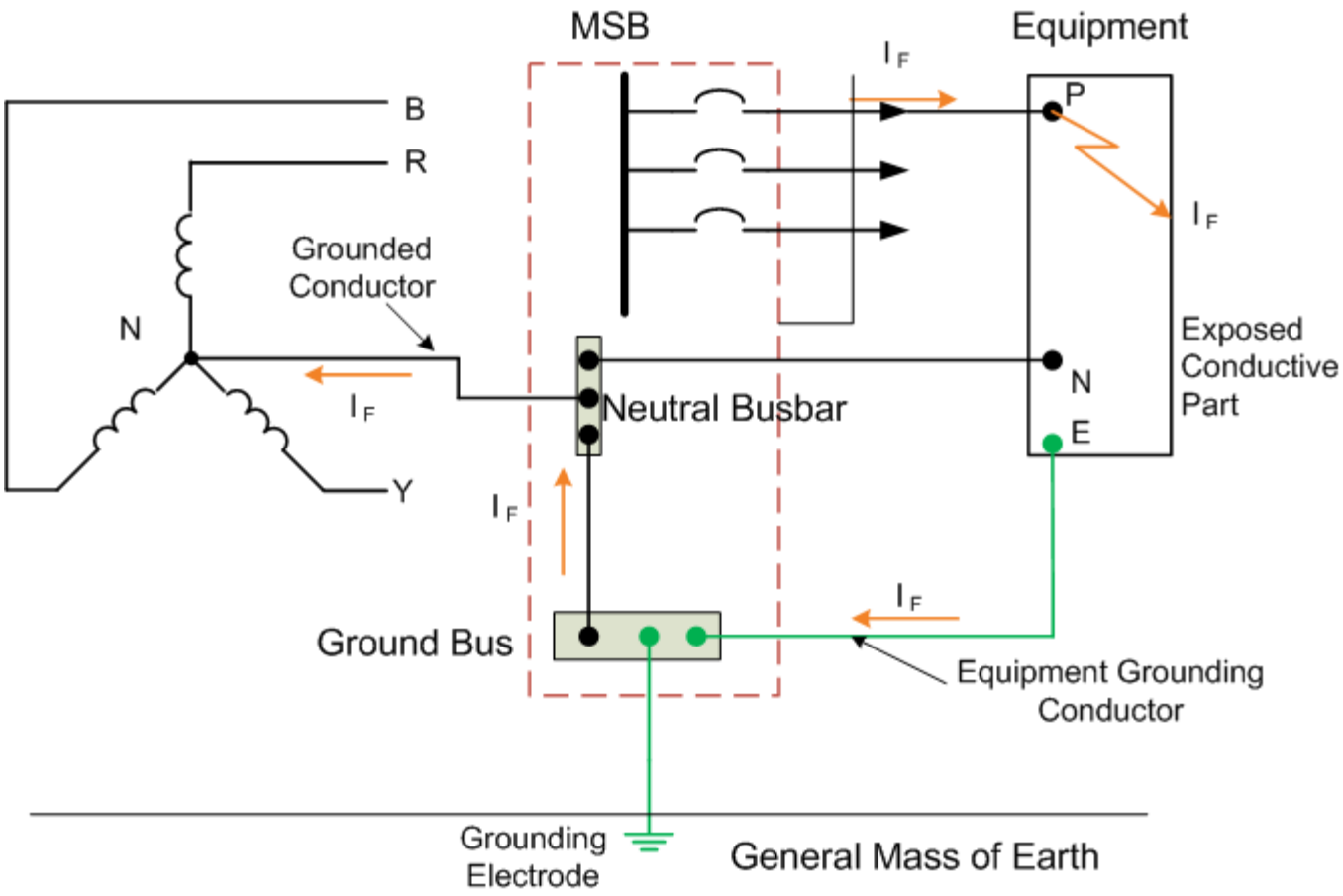
TN-C-S System


MSB
Equipment
B
R
N
Y
I_F
I_F
I_F
I_F
I_F
P
N
E
Exposed Conductive Part
Neutral Busbar
Link Neutral and Earthing Bar TNC-S
MET
MET
CPC
Supply Earth
General Mass of Earth

IEC TN-C System

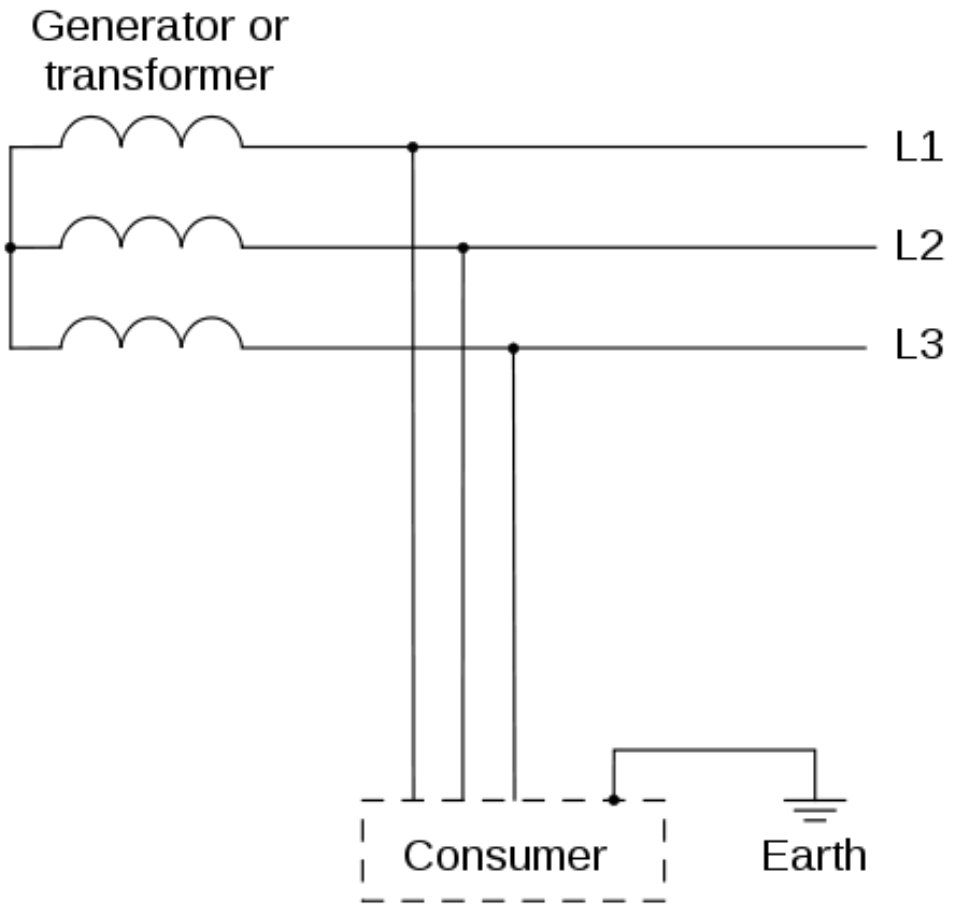


Grounding based on NEC



IEC IT System

A system having no direct connection between live parts and earth

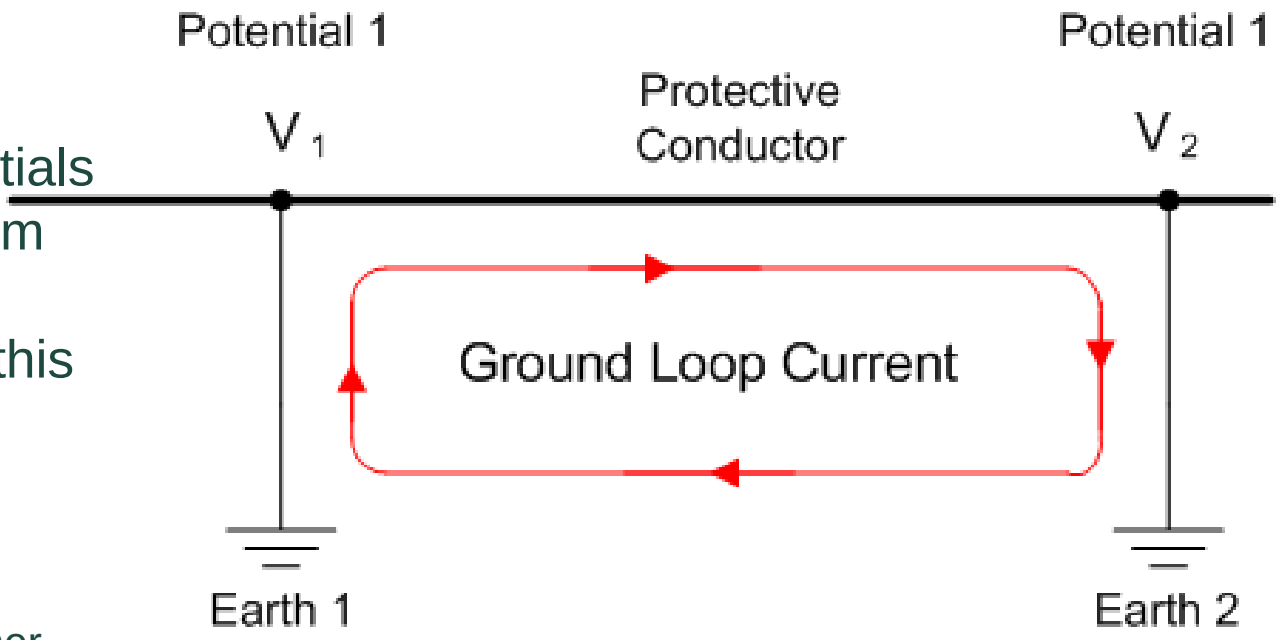


Ground Loop Definition

- A ground loop is a circuit that has more than one earth point connected to earth ground, with a voltage potential difference between the two earth points high enough to produce a circulating current in the earth system

GROUND LOOP CURRENT

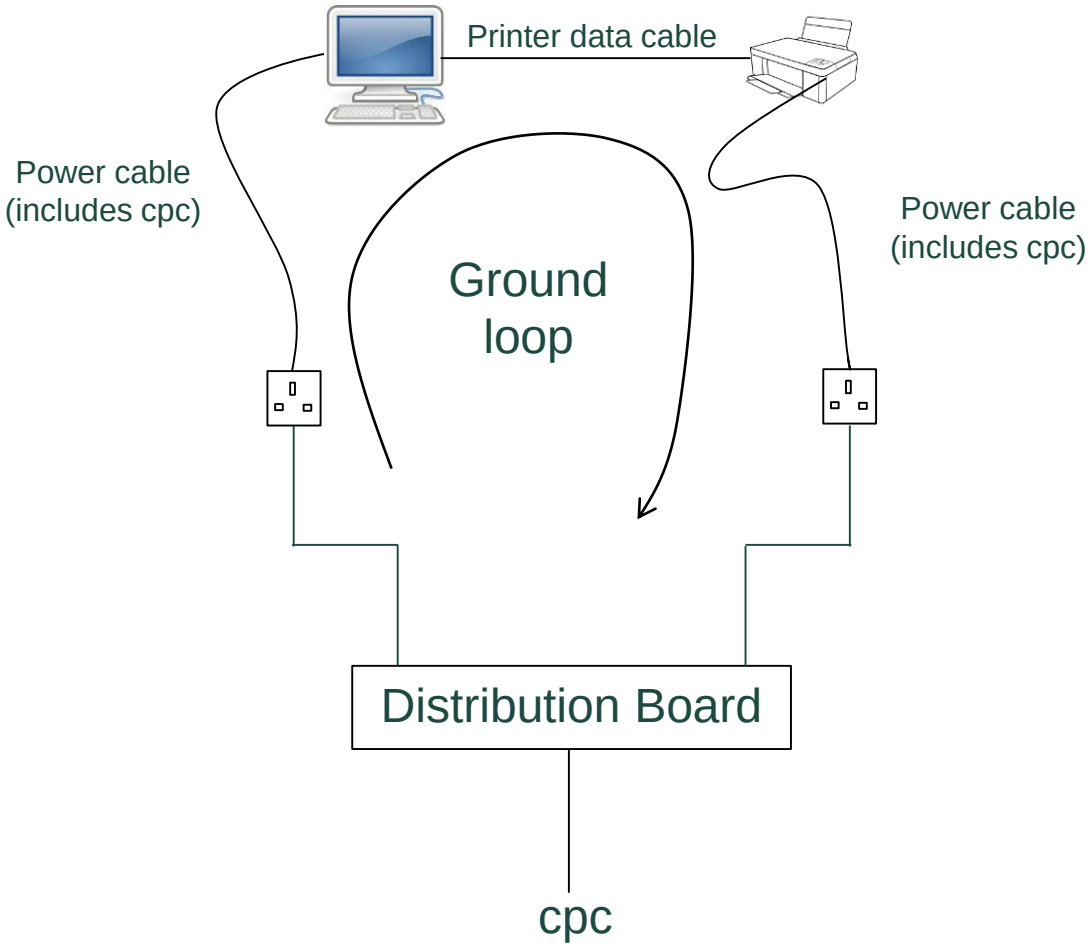
Slightly different potentials in the two power system grounds can cause circulating currents in this ground loop



For the ground loop current to flow, Voltage potential 1 must be higher than voltage potential 2

Ground loops can be undesirable because they create a path for noise currents to flow

Ground Loop Current



Separately Derived System (SDS)

- A system that supplies electrical power derived or taken from transformers, storage batteries, solar PV systems or generator sets
- An SDS is typically used to lower the power source impedance and isolate part of the power distribution system.
- SDS does not have electrical connections to any other part of the distribution system, a new earth reference is required

Separately Derived System (SDS)

- Wiring System Derived from a Generator set or Transformer with no Direct Electrical Connection to the Neutral Primary Conductors.
- Example: Isolation Transformer

SEPARATELY DERIVED SYSTEM

For a transformer

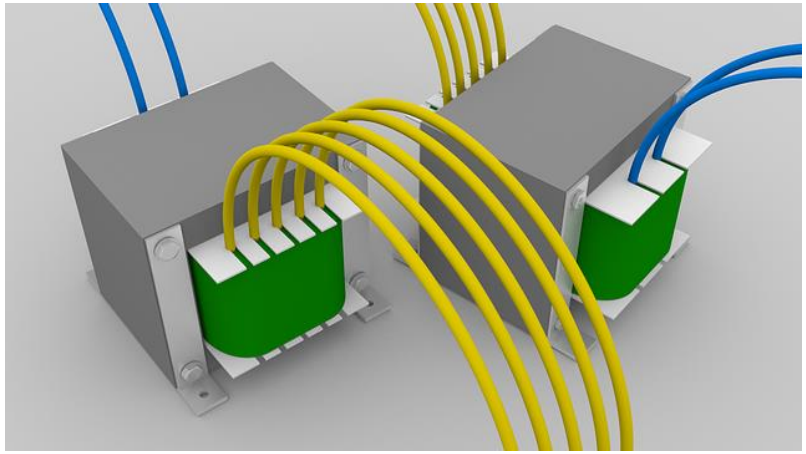
If there is a solid conductor connection between the primary and the secondary, it is not a SDS.

For a generator set

Look at the transfer switch, when a 4-pole transfer switch is use, then only the system is SDS

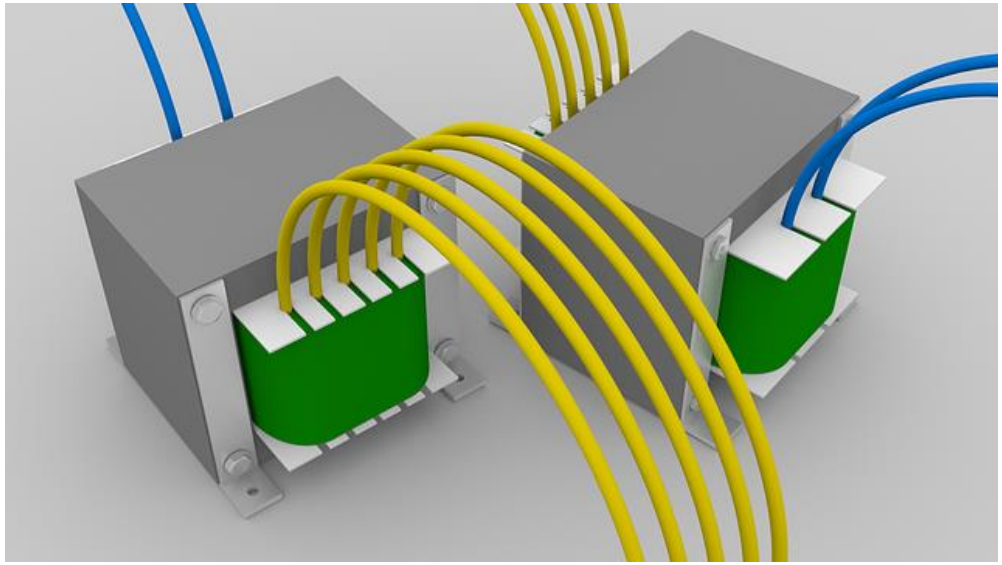
Isolation Transformer

- An isolation transformer has separate primary and secondary windings.
- It is recommended that a shielded isolation transformer be used. It contains an electrostatic shield between the primary and secondary winding that is connected to the tx earth terminal.



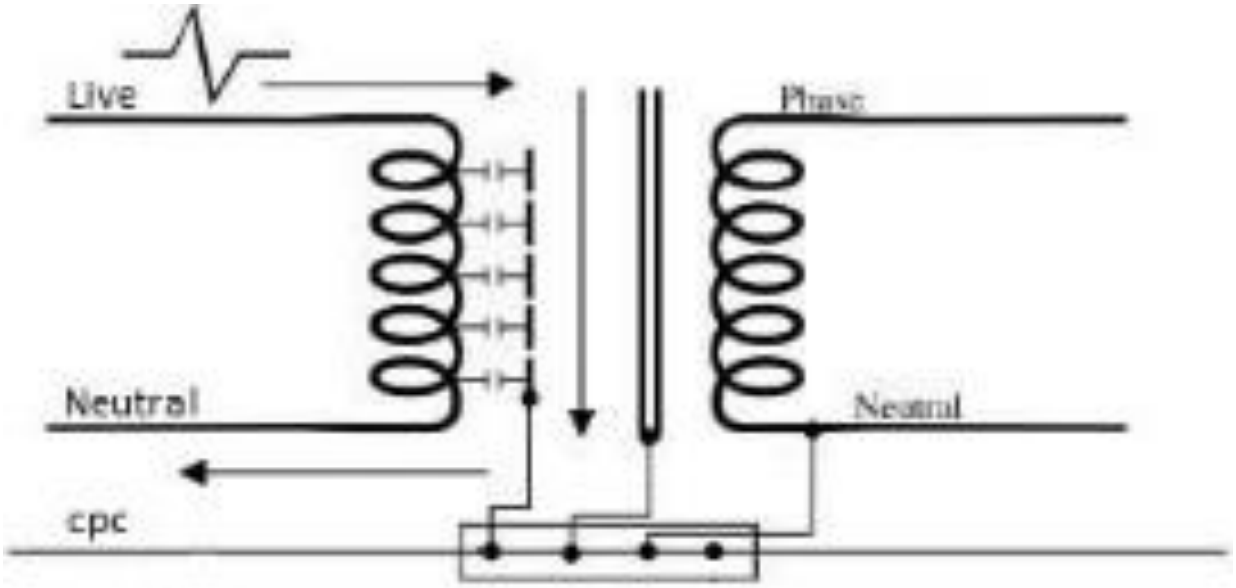
Isolation Transformer

- Electrostatic shield - additional conducting foil of nonmagnetic material (copper or aluminium) sandwiched between the primary and secondary coils. The foil essentially splits the primary to secondary winding capacitance into two

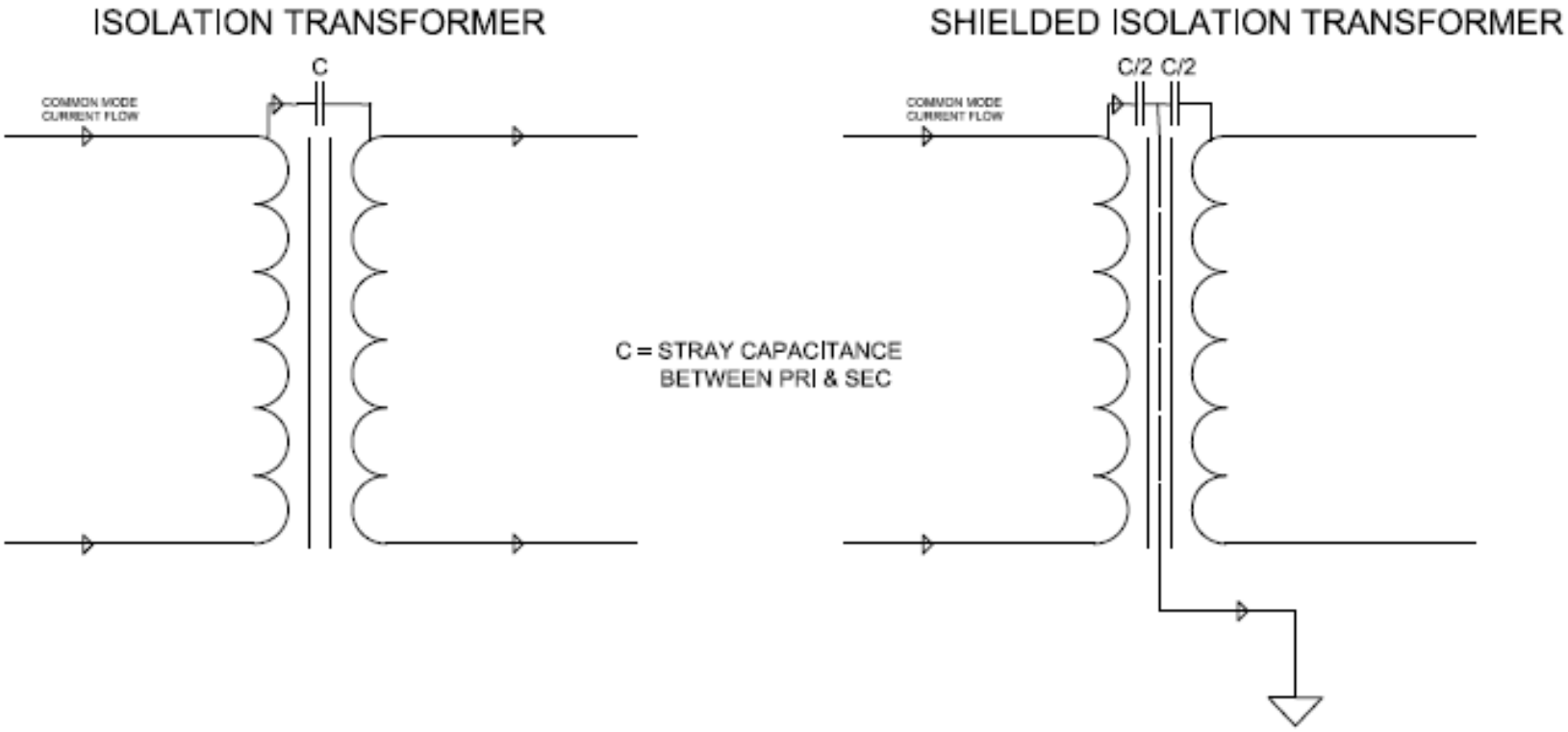


Isolation Transformer

- Providing an electrostatic shield between the primary and the secondary windings thus avoiding transfer of surge/impulse voltages passing through inter-winding capacitance



Isolation Transformer



Isolation Transformer

- Purpose:
  - Create a new neutral connection (a new small sub-station) as a “separately derived system”.
  - Lower source impedance by decreasing the distance between the load and the source.
  - Transfer the triplen (3rd, 9th, 15th, etc.) harmonics from the Y to the Δ of the isolation transformer. The triplen harmonics remain in the delta primary circulating around.

Isolation Transformer

- Purpose:
  - Reduction of N-E voltage. RCDs will trip at the instant when the neutral to earth voltage impulses occur.
  - Prevent the noise passing through the transformer to sensitive equipment
  - Prevent common-mode noise from reaching and damaging sensitive electronics equipment.
  - Isolate sensitive loads from transients.
  - Prevent circulating current in ground loops that could cause RCDs to activate unnecessarily (nuisance tripping).

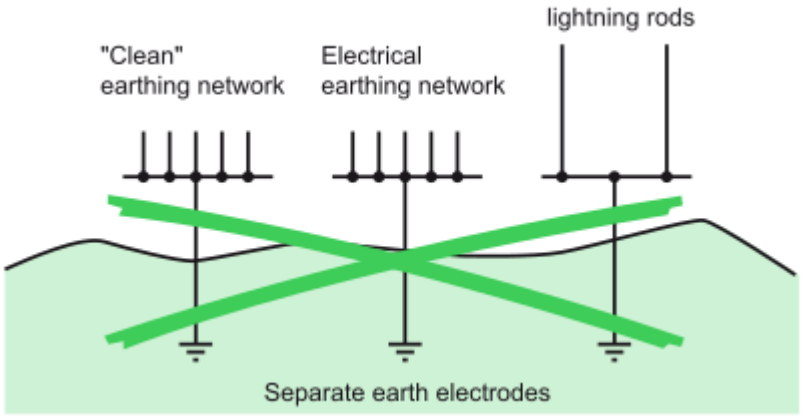
Isolation Transformer

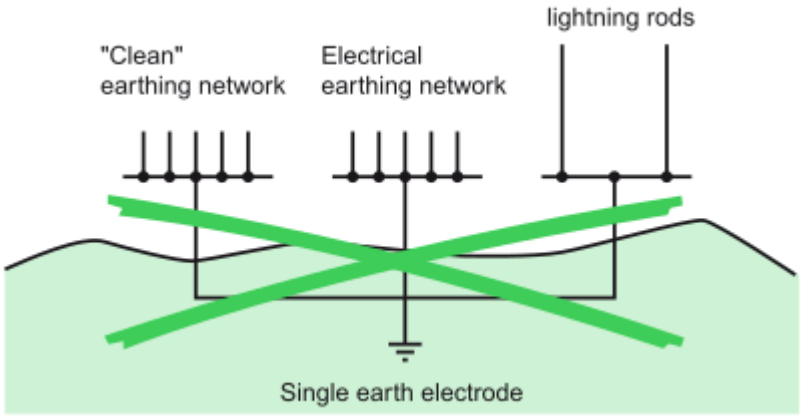
IEC 60364-4-44:2007 - Protection against voltage disturbances and electromagnetic disturbances

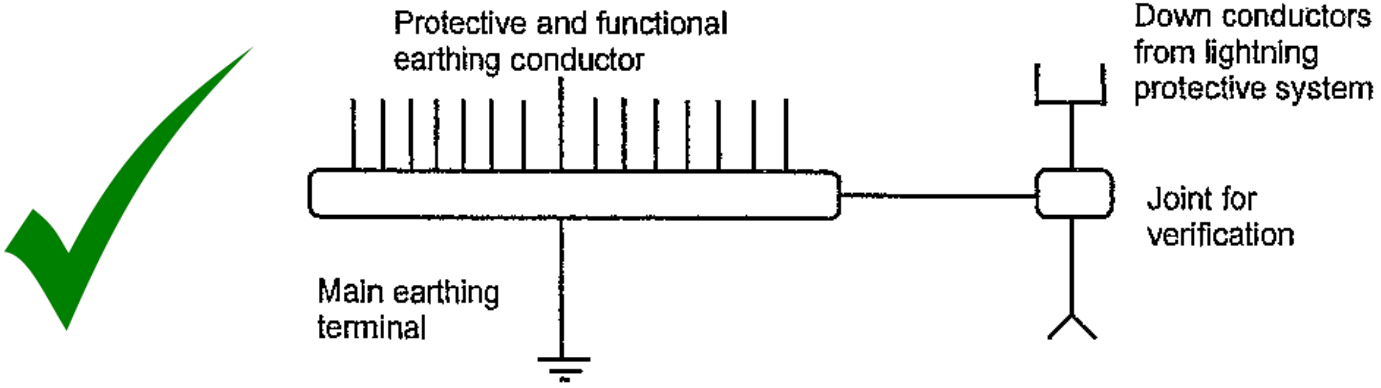
- Where there are problems in building installations due to electromagnetic influences (lightning, switching operations, short-circuits etc.):
  - use of double winding transformers. The secondary circuits should be connected as a TN-S system.

Interconnection of Earth Electrodes

IEC 60364-4-44:2007 - Protection against voltage disturbances and electromagnetic disturbances







Interconnected earth electrodes

Isolated Earth Electrodes

- Also known as “dedicated” or “independent”
- Electronics and Instrumentation Engineers feel that electrical earthing is “dirty earthing” and their equipment will fail, if all earthing systems are interconnected. They wish to keep a separate earthing system for their application.

Isolated Earth Electrodes

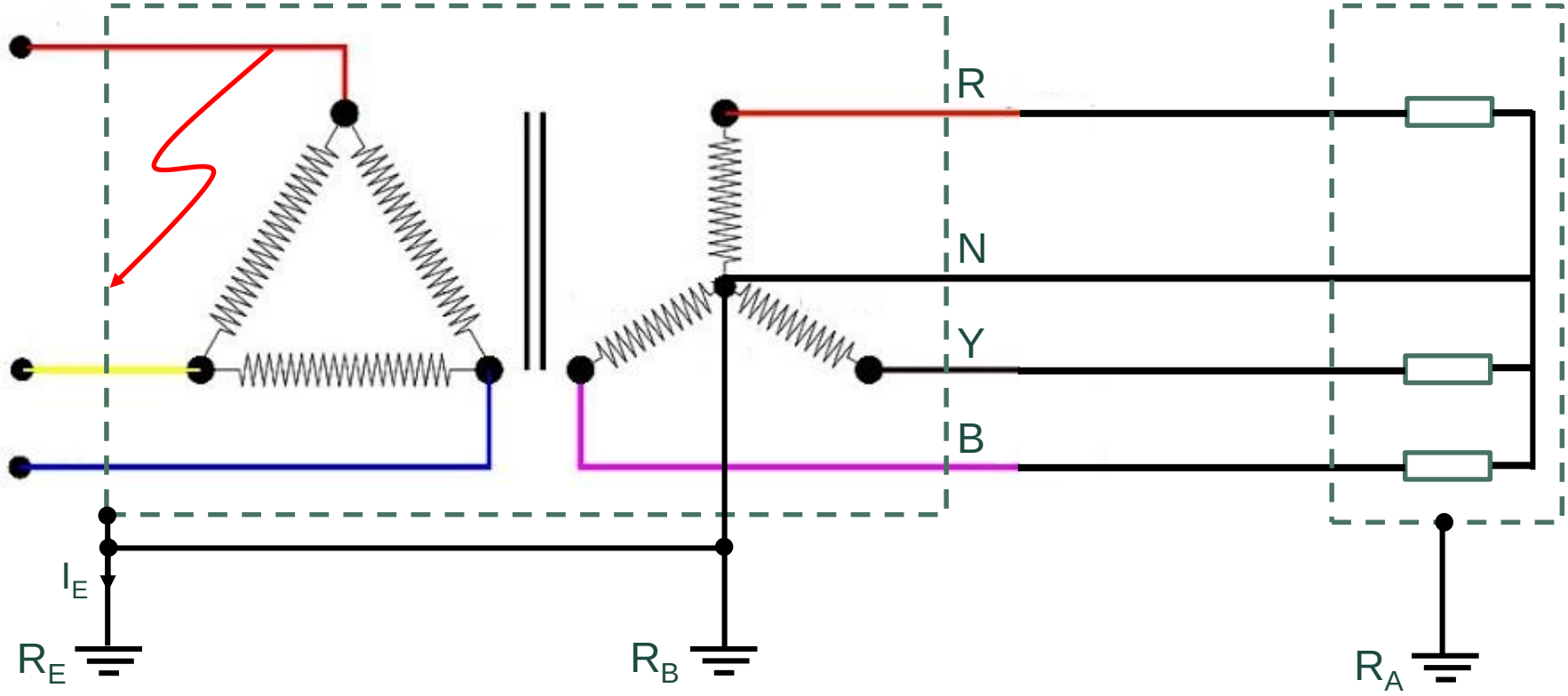
- This application is based on the incorrect assumption that all unwanted noise current can be drained into the earth and dissipated. This may be true for lightning.
- Electricity and interference flow in circuits: what goes in, must come out.
- Incorrect earthing can lead to unstable system operation.

Isolated Earth Electrodes

- An additional separate isolated earth electrode creates two earth references that are typically at different potential. This results in current circulating (ground loop) in an attempt to equalize different potentials

Overvoltages in LV Systems

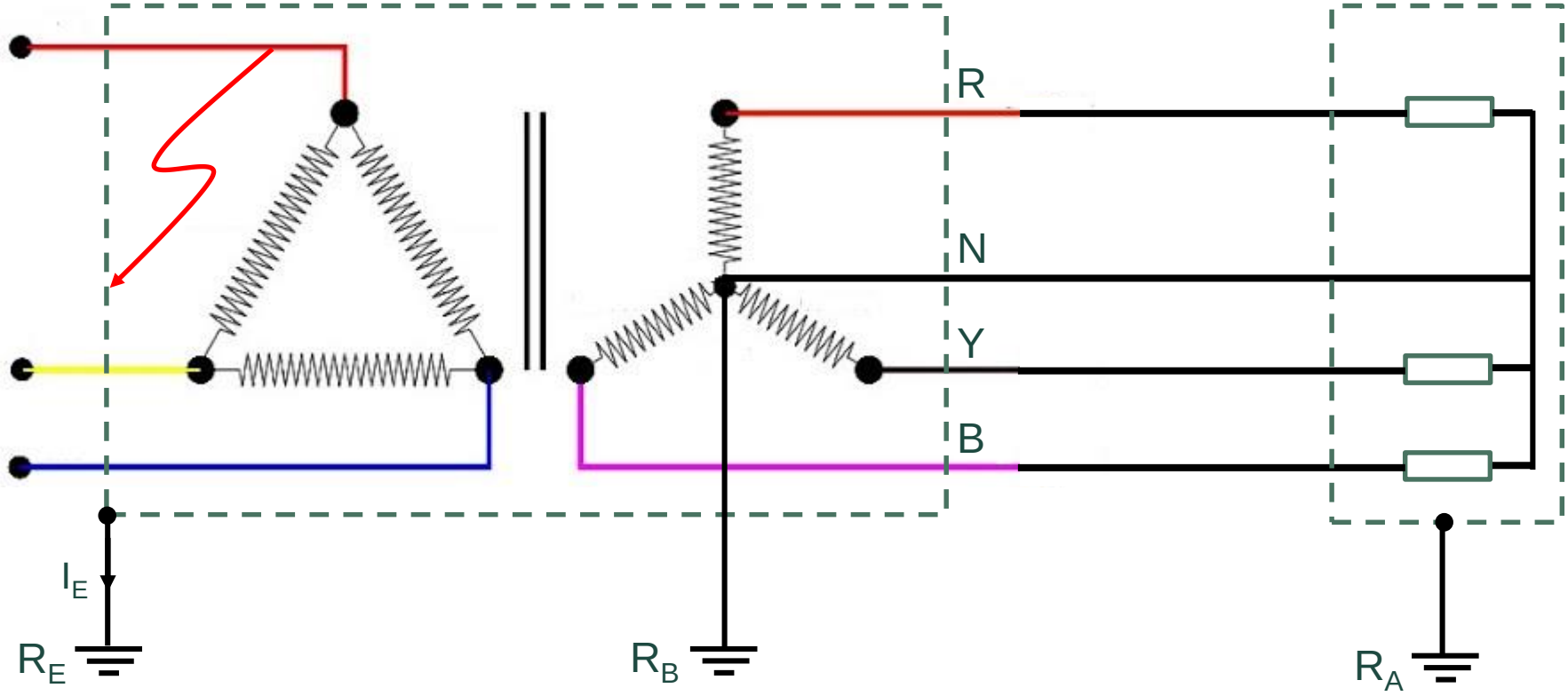
IEC 60364-4-44:2007 - Protection against voltage disturbances and electromagnetic disturbances



R_E and R_B connected: Voltage RE, YE, BE @ MSB = R_E x I_E + 230

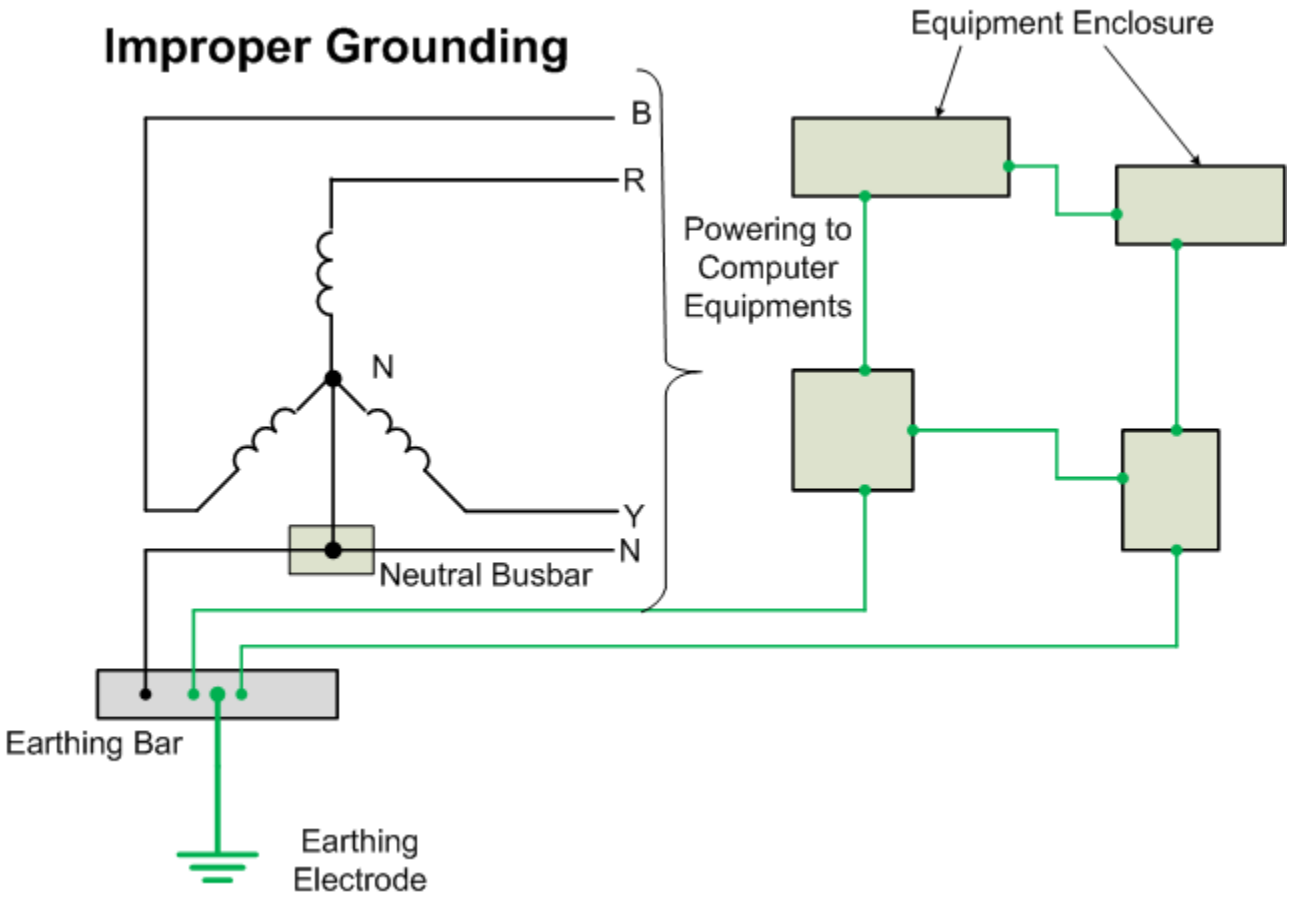
Overvoltages in LV Systems

IEC 60364-4-44:2007 - Protection against voltage disturbances and electromagnetic disturbances

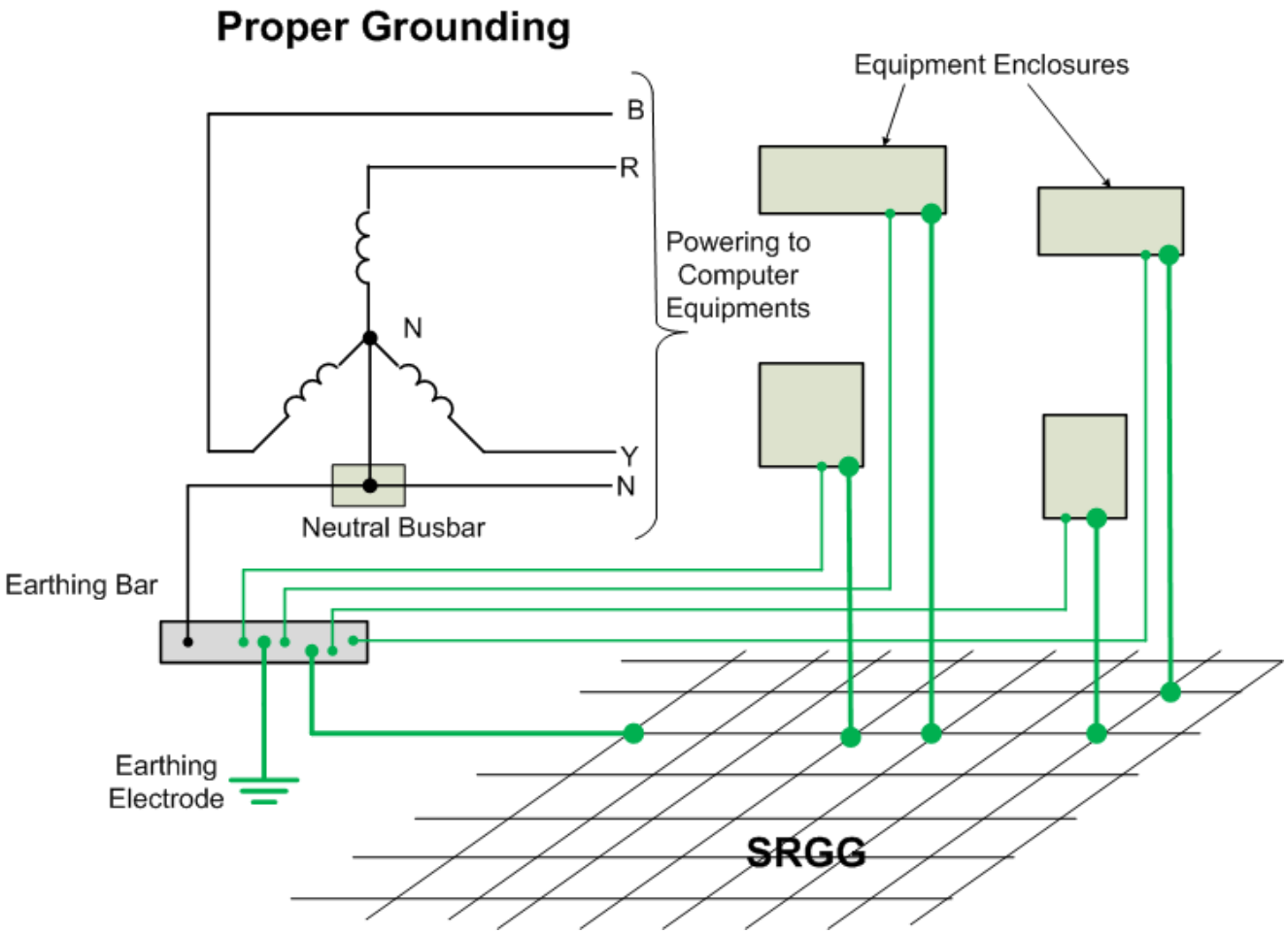


R_E and R_B separated: Voltage RE, YE, BE @ MSB = 230 V

HIGH FREQUENCY EARTHING



HIGH FREQUENCY EARTHING

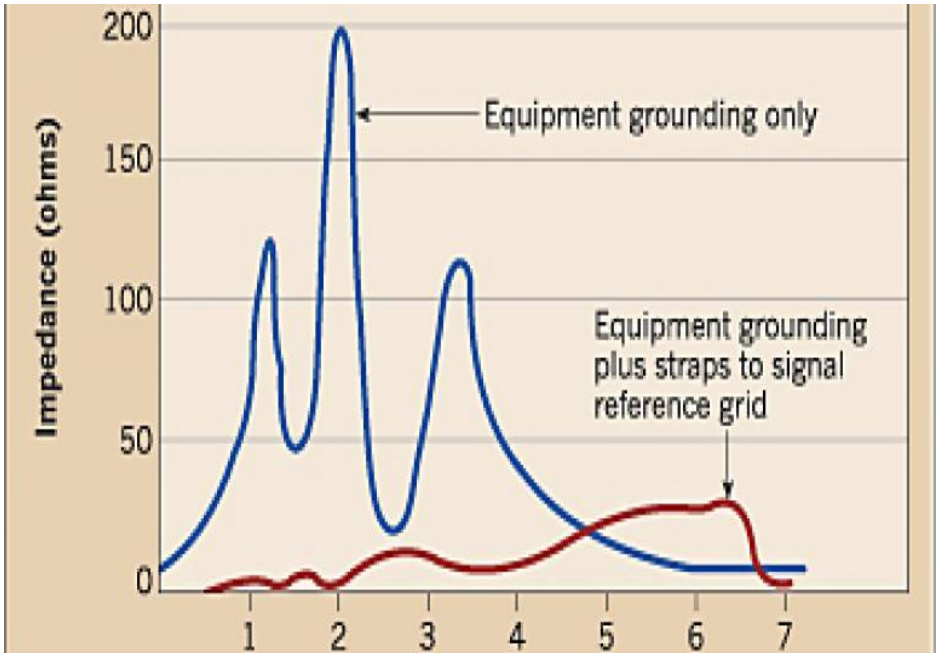


Signal Reference Grid (SRG)

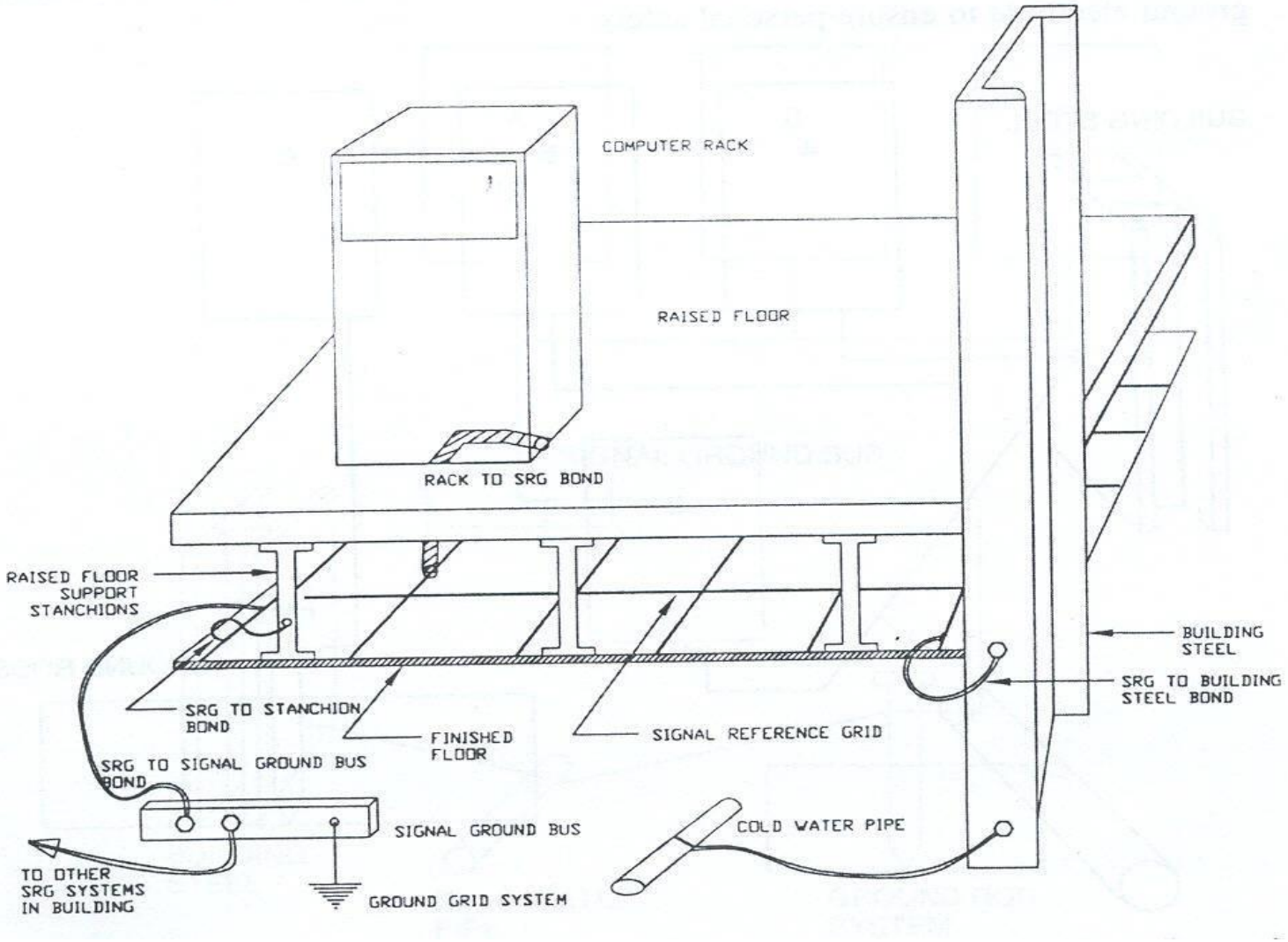
- To provide a common reference low-impedance plane from which sensitive loads may operate.
- To enhance the reliability of signal transfer between interconnected items of equipment by reducing inter-unit CM electrical noise.
- To prevent or minimize damage to inter-unit signal-level circuits and equipment power supplies when a power system earth fault events occurs.

Typical SRG Frequency vs. Impedance Characteristics

Comparison between earthing by Equipment Grounding Conductor (green wire) only
&
Earthing by broadband means where both EGC and a SRG



Typical and Communication Facility Data Center Grounding and Bonding



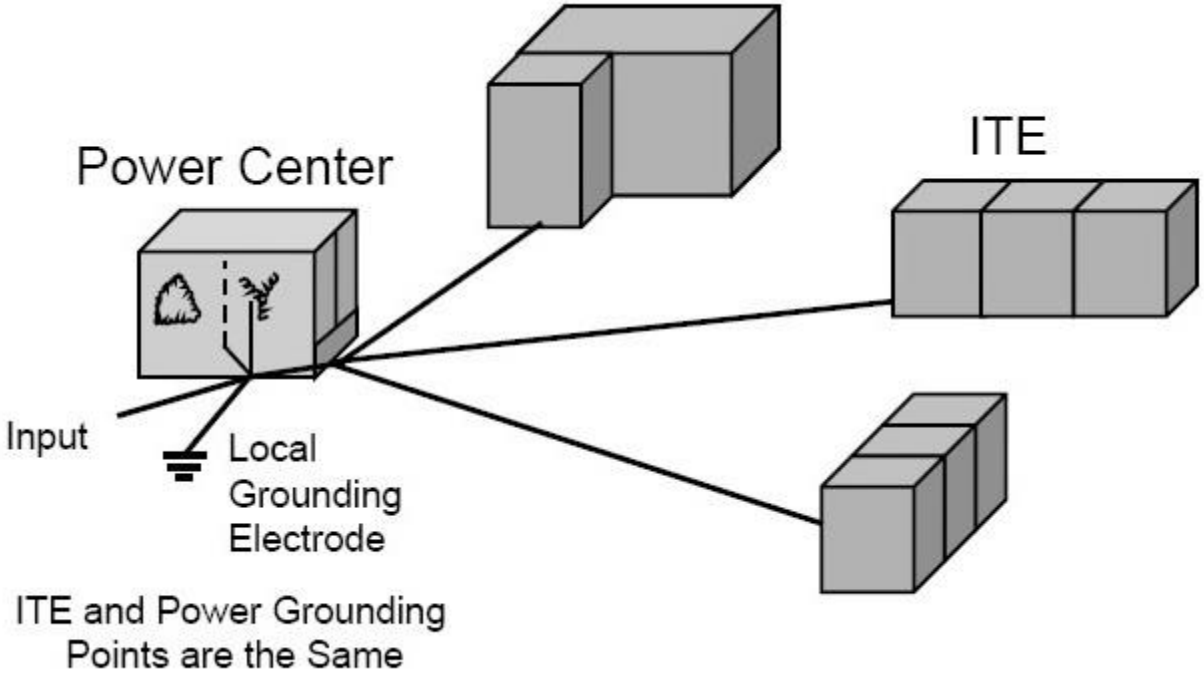
Signal Reference Grid Implementation

- Geometry of grid Determines Frequency Response
- Use Short Bonding Conductors – Flexible straps are preferred
- Bond to Power System Ground (Main Earthing Terminal at the MSB)
- Bond to Building Steel and to each metallic path within 6ft
- Bond all Miscellaneous.. (equipment and its associated …) Electrical Conductors to SRG
- All interconnecting Communications, Data, and Power Cables should lay on or very close to the SRG

Construction of SRG

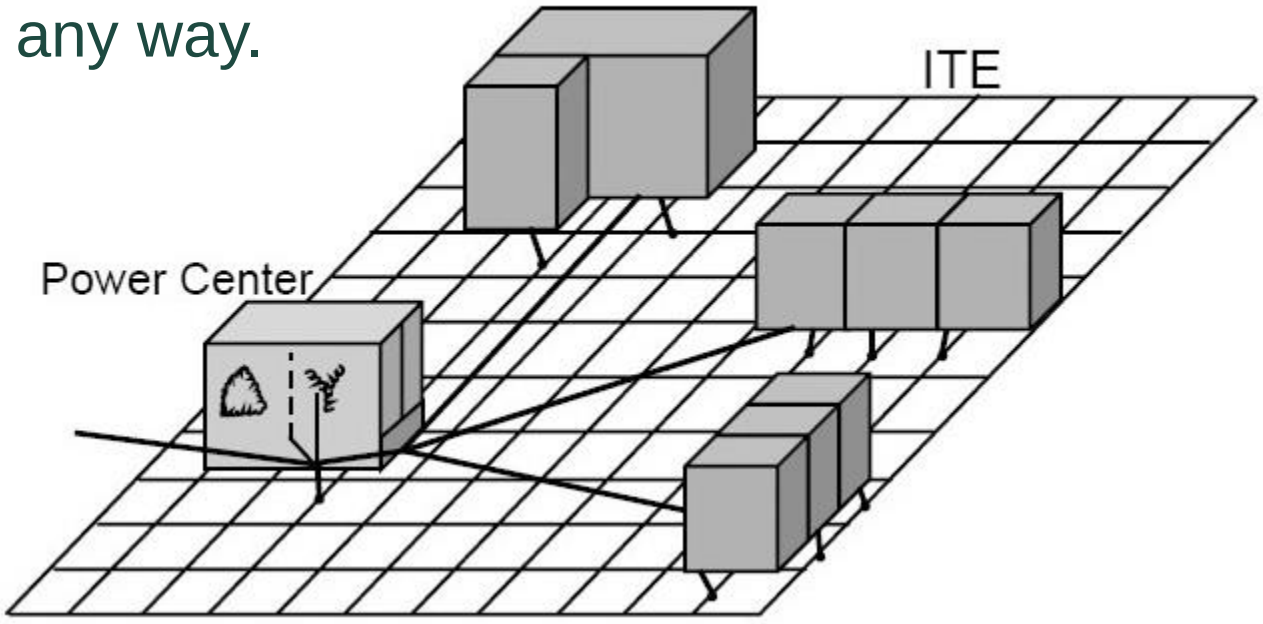
- SRG may be typically constructed using one of the following four methods (in decreasing order of effectiveness):
  - Solid covering of sheet metal
  - Grid of copper strips
  - Grid of copper or aluminum wire
  - Raised flooring substructure

Electrical and Earthing System Using EGC Only

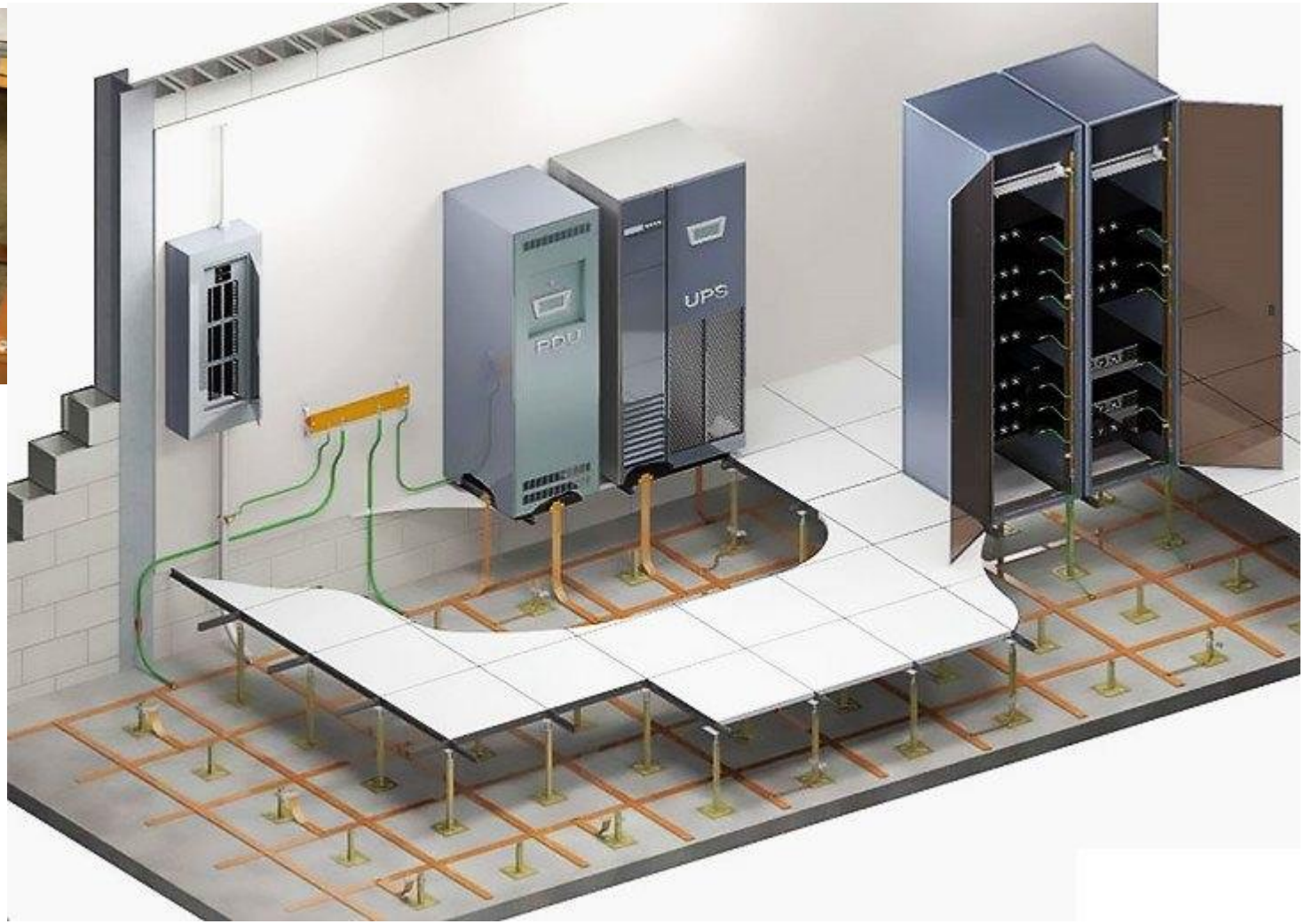


Electrical and Earthing System Combined EGC and SRG

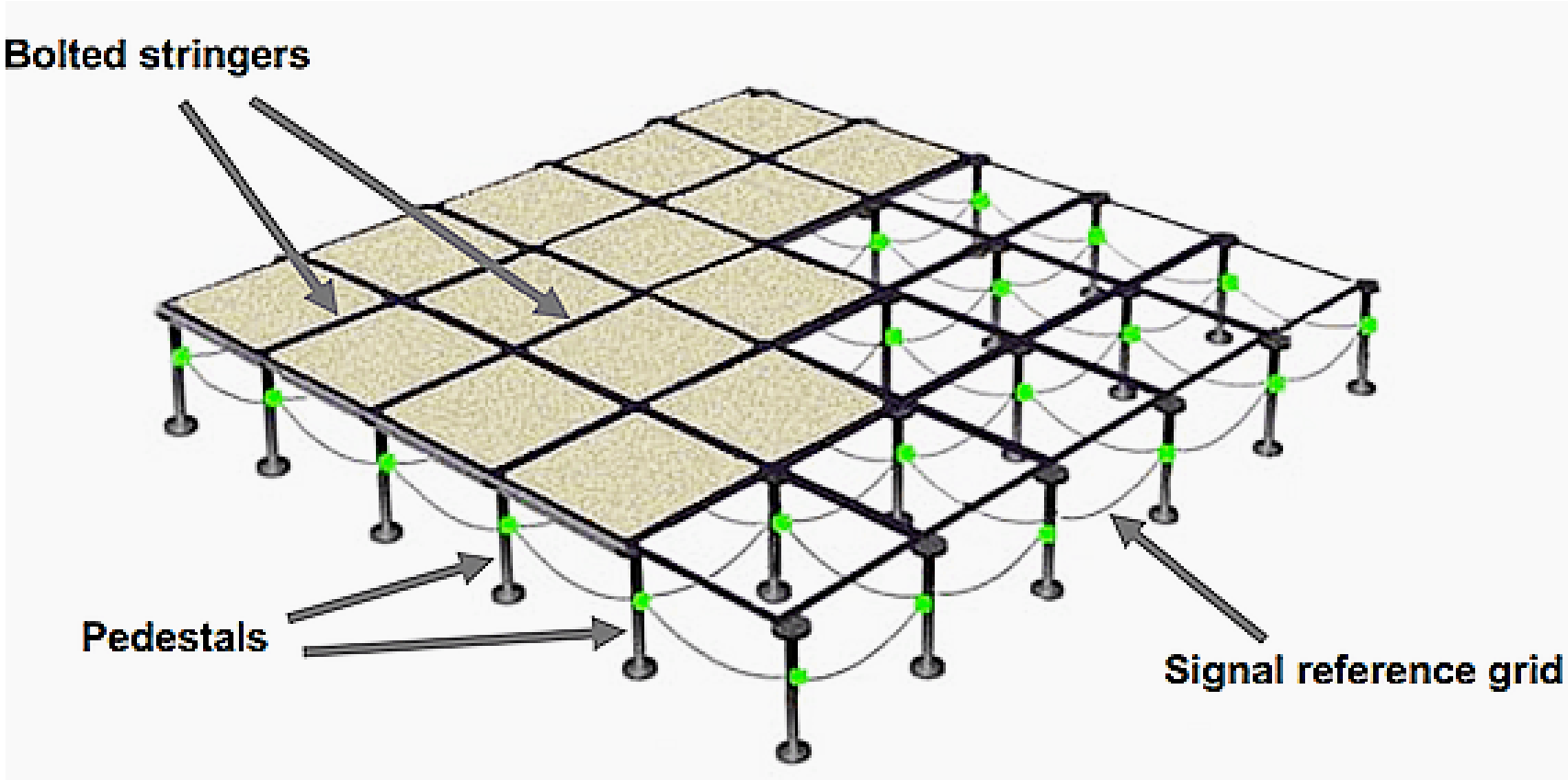
Recommended signal reference grid is combined with EGC connected in parallel and not isolated or insulated from one another in any way.



Signal Reference Grid Fabricated From Copper Strips



Raised Flooring Understructure



CONCLUSION
EFFECTIVE EQUIPMENT EARTHING

- Improper wiring and earthing is a source of power quality problems.
- Proper earthing is essential for personnel safety and effective sensitive electronic equipment performance.
- Earthing is the foundation of any electrical power, communication, or data-processing system, when the foundation is taken care of, the rest of the system will be stable.

References

[1] Fluke Corporation, "*Power Quality Troubleshooting*", 1998