Information Technology Industry Council (ITI, formerly CBEMA)

Information Letter

GUIDELINES FOR GROUNDING INFORMATION TECHNOLOGY EQUIPMENT (ITE)

Ninety percent (90%) of the problems with ITE installations are internal to the facility; only 10% are related to conditions on the utility electric service. Importantly, 75% of the problems arising within a facility are related to grounding making proper and adequate grounding the single-most important factor in reliable ITE system performance.

Purpose: To establish guidelines for grounding of power systems and equipment for ITE installations.

Scope: Computer room systems, distributed processing systems and stand alone systems.

Objective: To achieve a low impedance, common ground reference for all interconnected ITE (Information Technology Equipment) to prevent or reduce the likelihood of:

1. electric shock hazard;
2. equipment damage from transient voltage events;
3. data contamination or upset from noise voltage and currents in grounding connections.

Items 1 and 2 are typically due to low frequency (<100kHz) events; item 3 is typically due to high frequency (>100kHz) events.

Safe grounding is a legal requirement under OSHA Subchapter S encompassing the National Electrical Code (NEC) as well as state and local code statutes.

Safety Code Requirements. The requirements stated here are those of the U.S. 1996 National Electrical Code (NFPA 70) most directly applicable to the grounding of ITE. It is not an exhaustive list. Most jurisdictions adopt the National Electrical code as a local requirement, but may have additional requirements as well. The local electrical inspector has the power to enforce electrical code requirements within his or her jurisdiction.

NEC 250-5 Alternating Current Systems to be grounded.

(b) Ground AC premises wiring systems of 50-1000 volts under any of the following conditions:

(1) Where the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts;

(2) Where neutral is used as a circuit conductor in a 3-phase, 4-wire system;

(3) Where the midpoint of one phase is used as a circuit conductor in a 3-phase, 4-wire delta connected system;

(4) Where the grounded service conductor is uninsulated in accordance with the Exceptions to Sections 230-22, 230-30, and 230-41.

(d) Separately Derived Systems. A premises wiring system whose power is derived from generator, transformer, or converter windings and has no direct electrical connection, including a solidly connected grounded circuit conductor (neutral), to supply conductors originating in another system, if required to be grounded in (b) above, shall be grounded as specified in Section 250-26.

NEC 250-21 Objectionable Current over Grounding Conductors.

(b) If the use of multiple grounding connections results in an objectionable flow of current, one or more of the following alterations shall be made.

(1) Discontinue one or more, but not all such connections;

(2) Change the locations of the grounding connections;

(3) Interrupt the continuity of the conductor or conductive path interconnecting the grounding connections;

(4) Take other suitable remedial action as permitted by the local jurisdiction.

(d) Limitations to Permissible Alterations. The provisions of this section shall not be considered as permitting electronic equipment being operated on ac systems or branch circuits that are not grounded as required by this Article. Currents that introduce noise or data errors in electronic equipment shall not be considered as the objectionable currents addressed in this section.

NEC 250-23

(a) System Grounding Connections. ....The grounding electrode conductor shall be connected to the grounded conductor (neutral) at any accessible point from the load end of the service drop...to and including the terminal or bus to which the grounded service conductor is connected at the service disconnect.... A grounding connection shall not be made to any grounded circuit conductor (neutral) on the load side of the service disconnect.

In a separately derived system, (e.g. distribution transformer) a grounding electrode conductor shall be connected to the grounded conductor (neutral) in accordance with NEC 250-26.

NEC 250-26 A separately derived system required to be grounded by NEC 250-5 shall be grounded as follows:

(a) A bonding jumper of appropriate size shall connect the equipment grounding conductor (green wire) of the derived system to the derived system grounded conductor (neutral). This connection shall be made at any point on the separately derived system from the source to the first system disconnection means or overcurrent device.

A grounding electrode conductor of appropriate size shall be used to connect the grounded conductor (neutral) to the grounding electrode. ...This connection shall be made at any point on the separately derived system from the source to the first system disconnecting means or overcurrent device....

(c) The grounding electrode shall be as near as practicable to the system to be grounded and shall be:

(1) the nearest effectively grounded structural metal member of the structure;

(2) the nearest effectively grounded metal water pipe;

(3) other electrodes specified in 250-81 or 250-83 where (1) and (2) above are not available.

NEC 250-51 Effective Grounding Path. The path to ground from circuits, equipment and metal enclosures shall (1) be permanent and continuous; (2) have capacity to conduct safely any fault current likely to be imposed on it; and (3) have sufficiently low impedance to limit the voltage to ground and to facilitate the operation of the circuit protection devices.

The earth shall not be used as the sole equipment grounding conductor.

NEC 250-53 Grounding Path to Grounding Electrode at Services

(a) Grounding Electrode Conductor. A grounding electrode conductor shall be used to connect the equipment grounding conductors, the service equipment conductors, and where the system is grounded, the grounded service conductor to the grounding electrode.

(b) Main Bonding Jumper. For a grounded system. an unspliced main bonding jumper shall be used to connect the equipment grounding conductor and the service-disconnect enclosure to the grounded conductor of the system at each service disconnect.

NEC 250-54 Common Grounding Electrode. Where an ac system is connected to a grounding electrode in or at a building,...the same electrode shall be used to ground conductor enclosures and equipment in or at that building. Where separate services supply a building and are required to be connected to a grounding electrode, the same grounding electrode shall be used.

Two or more grounding electrodes that are effectively bonded together shall be considered as a single grounding electrode system in this sense.

NEC 250-74 Connecting Receptacle Grounding Terminal to Box.

Exception 4: Where required for the reduction of electrical noise (electromagnetic interference) on the grounding circuit, a receptacle in which the grounding terminal is purposely insulated from the receptacle grounding terminal shall be grounded by an insulated equipment grounding conductor run with the circuit conductors. This grounding conductor shall be permitted to pass through one or more panelboards without connection to the panelboard grounding terminal as permitted in Section 384-20 Exception so as to terminate directly at an equipment grounding conductor terminal of the applicable system or service.

FPN: Use of an isolated equipment grounding conductor does not relieve the requirement for grounding the raceway system and outlet box.

NEC 250-75 Bonding Other Enclosures.

Exception: Where required for the reduction of electrical noise (electromagnetic interference) on the grounding circuit, an equipment enclosure supplied by a branch circuit shall be permitted to be isolated from a raceway containing circuits supplying only that equipment by one or more listed nonmetallic raceway fittings located at the point of attachment of the raceway to the equipment enclosure. The metal raceway shall comply with the provisions of this article and shall be supplemented by an internal insulated equipment grounding conductor installed in accordance with Section 250-74, Exception 4 to ground the equipment enclosure.

FPN: Use of an isolated equipment grounding conductor does not relieve the requirement for grounding the raceway system.

NEC 250-81 Grounding Electrode System. If available on the premises at each building served, each of a-d below and any made electrodes in accordance with NEC 250-83 must be bonded together to form a grounding electrode system...

(a) Metal underground water pipe located less than 5 ft. from its entrance to the building (when augmented by at least one of b-d below or made electrodes per NEC 250-83);

(b) Metal frame of the building (where effectively grounded);

(c) Concrete encased electrode (generally formed by the rebar in the building foundation);

(d) Ground ring.

NEC 250-83 Made and Other Electrodes. Where none of the above are available, one or more of the electrodes in b-d below shall be used.

(a) A metal underground gas piping system shall not be used as a grounding electrode;

(b) Other local underground systems and structures;

(c) Rod or pipe electrodes;

(d) Plate electrodes.

NEC 250-91

(b) The equipment grounding conductor run with or enclosing the circuit conductors shall be one or more ... of the following: (1) copper or other corrosion resistant conductor ... insulated, covered or bare; solid or stranded or busbar; (2) rigid metal conduit, (3) intermediate metal conduit, (4) electrical metallic tubing, (5) flexible metal conduit and fittings where listed for such service, (6) armor of Type AC cable, (7) copper sheath of mineral insulated metal shielded cable, (8) metallic sheath and/or grounding conductors of Type MC cable, (9) cable trays as permitted in Sections 318-3(c) and 318-7, (10) cablebus framework as permitted in Section 365-2(a)....

(c) Supplementary grounding electrodes shall be permitted to augment equipment grounding conductors (provided all of the NEC grounding conductors are installed per applicable sections of Article 250), but earth shall not be used as the sole grounding conductor.

In other words, extra driven ground rod or rods may be used to augment the grounding system, but if used, must be connected using an acceptable grounding electrode conductor to other grounding electrodes listed above. An isolated earth ground is prohibited by the NEC.

NEC 384-20 ....In panelboards, equipment grounding conductors shall not be connected to a terminal bar provided for grounded conductors (neutrals) unless the bar is identified for the purpose and is located where connection is made from the grounded conductor to a grounding electrode conductor as permitted by Article 250.

NEC 645-15 Electronic computer/data processing equipment (in an electronic computer/data processing room) shall be grounded in accordance with Article 250 or double insulated. Power systems derived within listed electronic computer/data processing equipment that supply electronic computer/data processing systems through receptacles or cable assemblies supplied as part of this equipment shall not be considered separately derived for the purpose of applying Section 250-5(d). All exposed, noncurrent carrying metal parts of an electronic computer/data processing system shall be grounded.

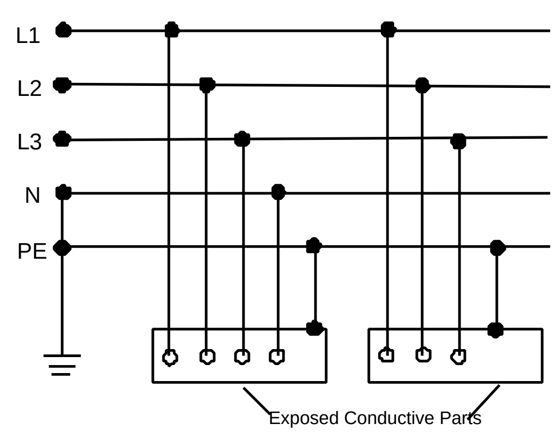
OTHER POWER SYSTEMS

Power systems with the neutral conductor solidly bonded to the grounding electrode conductor at an on-premises point in the distribution system, may not always be the case particularly at locations outside North America. Meeting the objective of this paper is still a requirement for acceptable system performance. Follow the recommendations as closely as possible as permitted by local or national electrical codes.

Described below are five recognized power grounding schemes. In international terminology, the Grounding Conductor (G) is termed the “Protective Earth Conductor (PE)”.

TN (Terra Neutral) Power Systems are those systems having one point directly connected to Ground (Earth) by Protective Earth Conductors. There are three types of TN power systems:

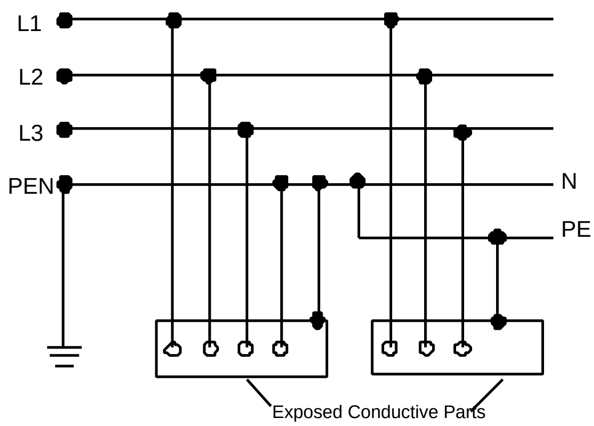
TN-S (Terra Neutral-Separate) - Separate Neutral and Protective Earth conductors exist throughout the system.



TN-S Power System

FIGURE 1

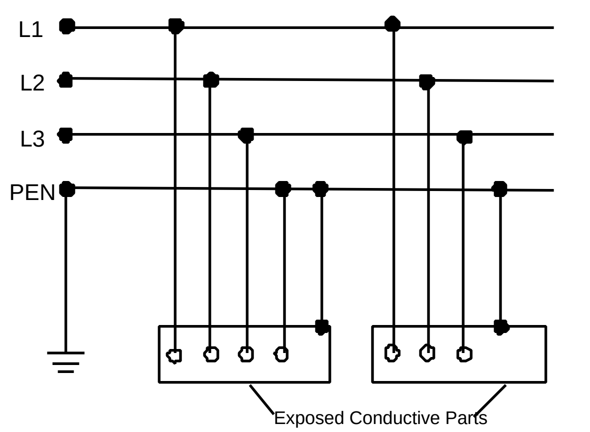
TN-C-S (Terra Neutral-Combined-Separate) – Neutral and Protective Earth functions are combined in a single conductor in part of the system.



TN-C-S Power System

FIGURE 2

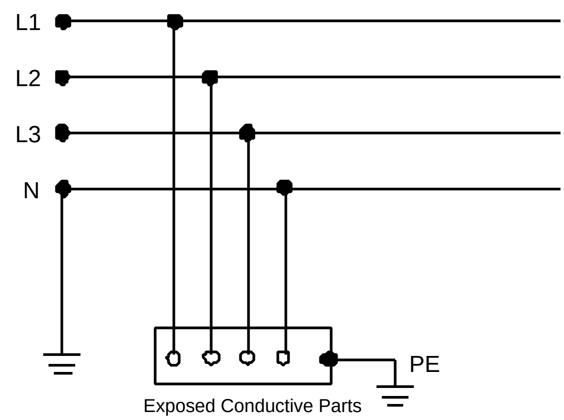
TN-C (Terra Neutral-Combined) – Neutral and Protective Earth functions are combined in a single conductor throughout the system.



TN-C Power System

FIGURE 3

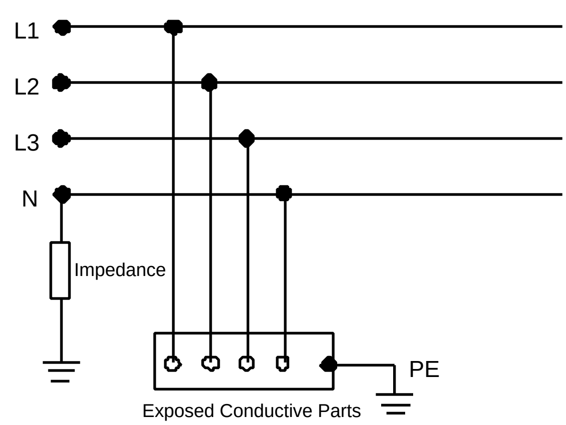
TT (Terra Terra) Power Systems are those having one point directly connected to Ground (Earth), but the exposed conductive parts of the installation are connected to grounding electrodes independent of the grounding electrodes of the power system.



TT Power System

FIGURE 4

IT (Impedance Terra) Power Systems have no direct connection to Ground (Earth), the exposed conductive parts of the installation are directly connected to Ground. Also called an impedance grounded system.



IT Power System

FIGURE 5

GROUNDING METHODS

General

1. In panelboards up to 100A serving IT equipment, an insulated grounding conductor the same size and run in the same raceway as the feeder conductors should be used. In panelboards >100A, size the insulated grounding conductor in accordance with NEC Table 250-95, except the grounding conductor should never be smaller than #4.

If the panelboard is not the point where neutral and equipment ground are connected, then separate neutral and equipment ground buses must be used.

2. Metal raceways (conduits, etc.) should not be used as the sole grounding conductor for ITE circuits. An insulated equipment grounding conductor is always recommended for feeder circuits and branch circuits serving IT equipment.

3. IT equipment should be powered from dedicated branch circuits wherever possible. A dedicated branch circuit not only has its own breaker, but also its own grounding conductor (ground) and grounded conductor (neutral) if used; neither of which is to be shared with other circuits.

4. For cord connected equipment, dedicated branch circuits for ITE may be terminated in IG (isolated ground) receptacles. Doing so eliminates multiple ground paths which may be a source of noise in the circuit. IG circuits are not a panacea for all branch circuit grounding concerns. They are most effective where served from dedicated, separately derived, locally grounded sources. IG circuits will not improve grounding conditions when served from sources which, due to improper wiring or faulty load equipment, already have currents flowing on grounding conductors.

5. In branch circuits serving ITE, a grounding conductor (green wire or green wire with yellow stripe) the same size as the circuit conductors shall be run in the same metal raceway with the circuit conductors.

6. When IT equipment is served by a separately derived system (such as a transformer), that system should be grounded with the neutral-ground bond made as in Figure 6A. IT equipment uses the equipment grounding conductor as a logic reference and that reference must be stable. For all applications, it is preferred that distance "D" be as short as possible.

FIGURE 6-A

RECOMMENDED

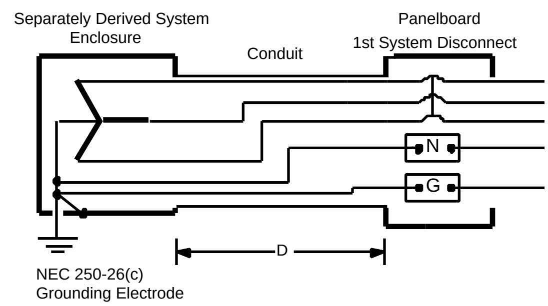
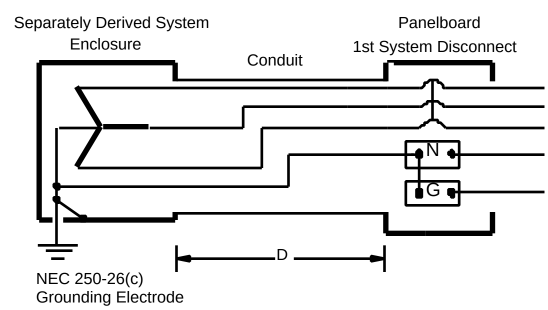


FIGURE 6-B

<u>NOT</u>
RECOMMENDED



<u>It is not recommended</u> to make the neutral-ground bond as in Figure 6B because current flowing in the grounded conductor (neutral) between the panelboard and separately derived system (transformer) causes instability (noise) in the ground reference. Furthermore, if the ground bus in the panelboard is not insulated from the panelboard, the panelboard, conduit and separately derived equipment enclosure forma parallel neutral current return path. Parallel neutral current return paths also

exist via equipment grounding conductors in branch circuit-connected equipment.

7. Where IG equipment grounding conductors are used, they may be terminated to a separate insulated grounding bus in the panelboard. The insulated bus is then connected using an insulated equipment grounding conductor to the Xo grounding point of the transformer

8. Many UPS (uninterruptible power supplies) with bypass circuits; MG (motor generators) with bypass circuits; standby or emergency engine generators; are solidly interconnected systems, not separately derived systems. The output grounded conductor (neutral) is solidly interconnected to the service supplied (utility) system grounded conductor. (See Figure 7)

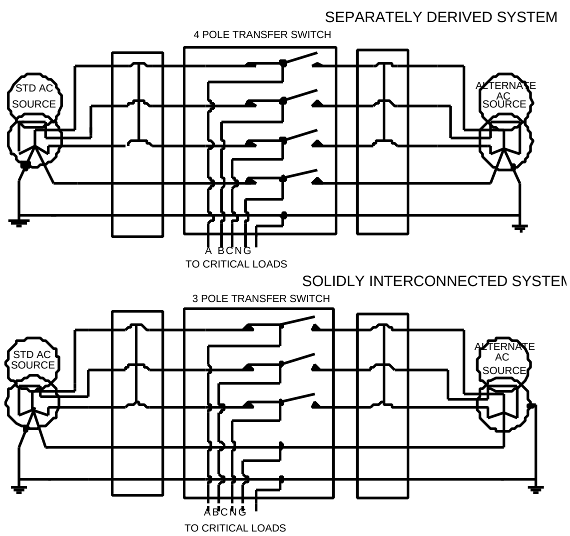


FIGURE 7

Computer Rooms (See Figure 8)

1. All panelboards, grounding conductor connections to information technology equipment, grounded data cables penetrating the room, transient suppressor plates, if used, and zero signal reference grid, if used, should be bonded to a common ground reference.

2. A dedicated power source such as an isolation transformer or PDU (power distribution unit) should be used to power all equipment in a data processing room. Ground computer room power sources in accordance with NEC 250-26 or 645-15.

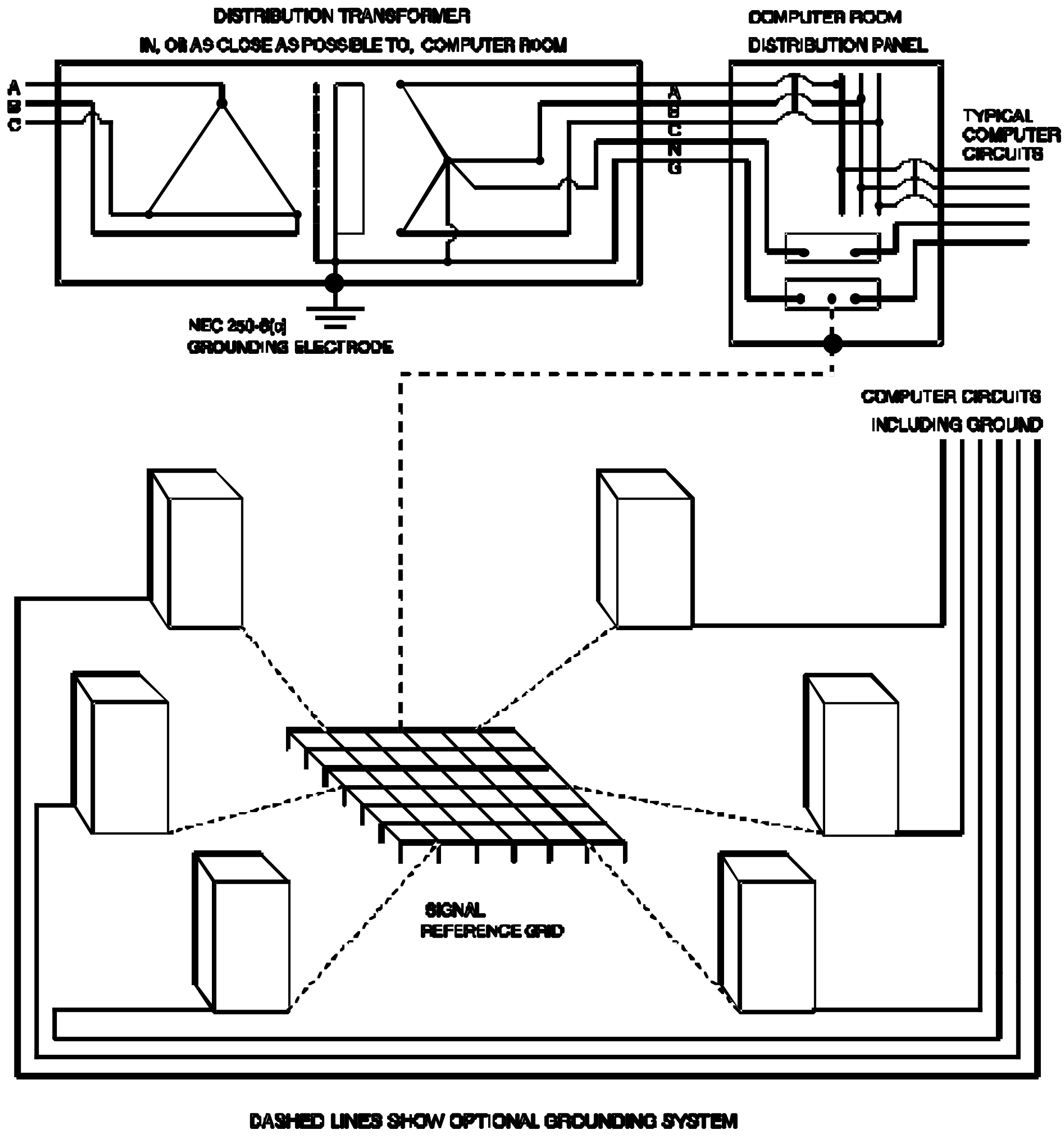
3. Dedicated power sources and panelboards serving computer rooms should be located in, or as near as possible to, the computer room.

When multiple power sources (isolation transformers, etc.) supply power to a data processing room, bond together grounding electrode conductors from each unless doing so results in objectionable current flow in the grounding system.

4. Branch circuit grounding conductors, raceways, grounding electrode conductors may not have low enough impedance to effectively ground high frequency signals. If such is the case, data contamination and mis-operation may result from noise voltage propagating on grounding conductors.

If acceptable to the ITE manufacturer, a SRG (signal reference grid) may be used to provide a nearly constant potential, low impedance, high frequency, signal reference grounding system. An effective SRG may be formed using the 2 ft. x 2 ft. stringers of a raised floor. The stringers must be bolted together and suitably plated to give low resistance. A stringerless raised floor <u>may not be used</u> for this purpose as the floor panels do not form a solidly interconnected grid. As an alternative, a 2 ft. x 2 ft. SRG using 2" strips of continuous sheet copper, aluminum, zinc plated steel, or any number of pure and composite metals with good surface conductivity may be locally made or purchased finished. The SRG is bonded to the metal cabinets of all IT equipment using a flat, braided copper strap as short as possible, preferably 2 ft. or less in length, and for safety purposes, to the grounding conductor serving the dedicated ITE panelboard(s). Such a grid will effectively ground high frequency signals up to about 20Mhz.

FIGURE 8


DISTRIBUTION TRANSFORMER
IN, OR AS CLOSE AS POSSIBLE TO, COMPUTER ROOM
COMPUTER ROOM
DISTRIBUTION PANEL
A
B
C
A
B
C
N
G
TYPICAL
COMPUTER
CIRCUITS
NEC 250-5(d)
GROUNDING ELECTRODE
COMPUTER CIRCUITS
INCLUDING GROUND
SIGNAL
REFERENCE GRID
DASHED LINES SHOW OPTIONAL GROUNDING SYSTEM

Distributed Processing Systems (See Figure 9)

Distributed processing systems and local area networks (LAN's) are those with multiple processing units separated and remote from each other. These individual processors may be powered from the same or separate panelboards on the same electric service, or separate services in separate structures.

When processors or peripherals of a distributed processing system are located in separate buildings powered from separate electric services; if practicable, bond together the grounding electrode conductors of each service using existing metallic structures such as rigid metallic conduit, water pipes, etc. or pull a #4 or larger buried copper conductor so that earth is not the sole grounding connection between/among services. The metallic connection will attenuate steady state low frequency potential differences between or among services. It will not adequately attenuate transient impulse potential differences. Transient suppressors, optical isolators or fiber optic links are necessary to eliminate or reduce transient impulse activity to tolerable levels.

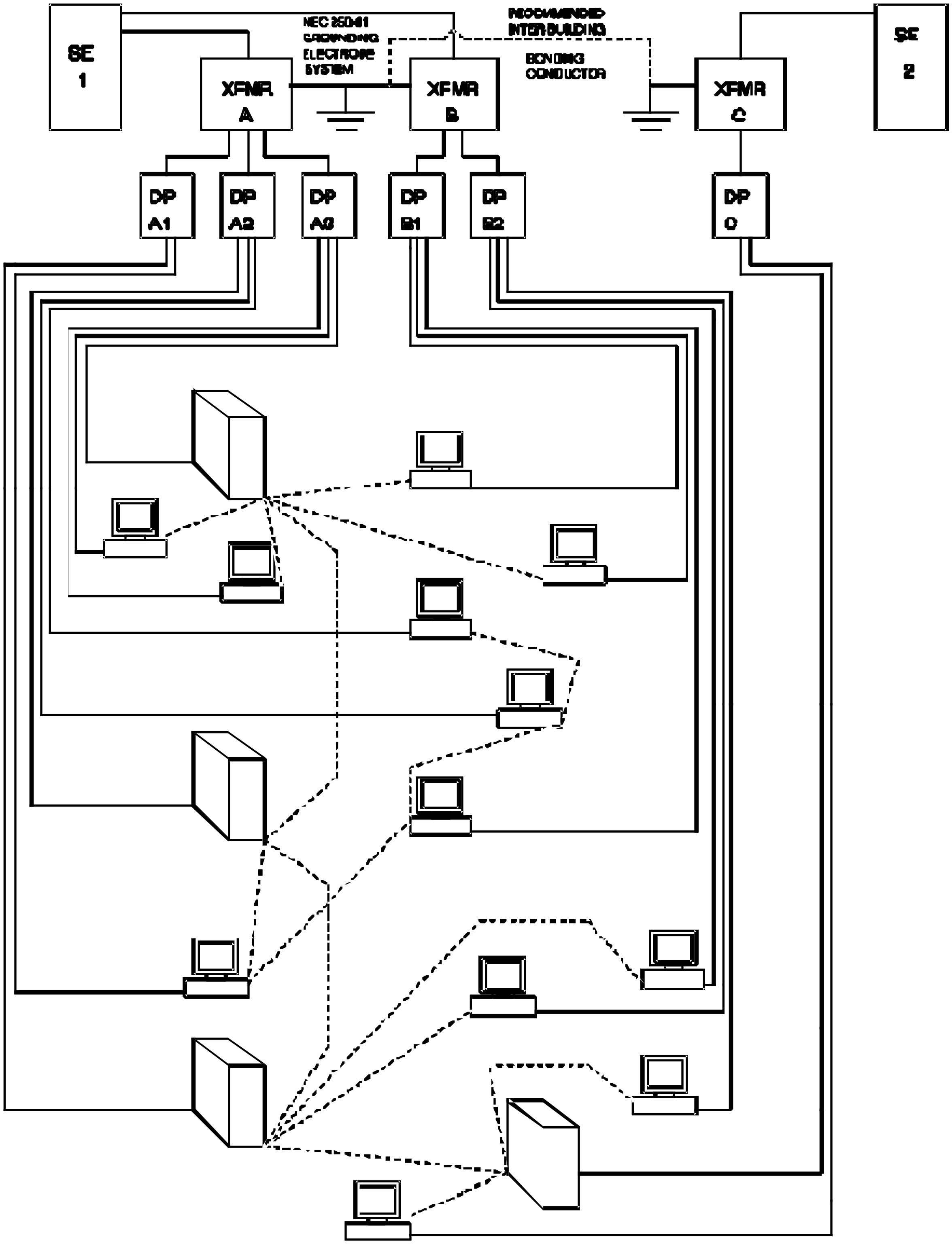
When system components are located in the same structure but powered from separate panelboards and perhaps from distinct separately derived systems, multiple ground paths are present. These paths arise from planned connections (raceway and ground wire connections to the service entrance), incidental connections (raceway physical connections to structural steel, piping systems etc.) and data cable connections between/among IT equipment.

Dedicated circuits are strongly recommended for ITE circuits, and IG circuits may be recommended to limit ground paths and noise pickup in those paths. To further reduce ground noise problems, data cables can be electrically decoupled using line drivers, multiplexors, modems, optical isolators, fiber optic links, etc. Any such practice must have the approval of the ITE manufacturer to assure it does not defeat EMI (electromagnetic interference) control mandated by the FCC.

Figure 9 Legend:	
SE	Service Entrance
XFMR	Transformer
DP	Distribution Panel
Solid Lines	Power Wiring
Dashed Lines	Data Cabling

FIGURE 9

DISTRIBUTED PROCESSING SYSTEM
POWER WIRING AND DATA CABLE WIRING



DEFINITIONS

Ground: A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

Grounded conductor: A system or circuit (current carrying) conductor that is intentionally grounded. The neutral wire. (white, domestic; blue, international).

Grounding conductor: A conductor used to connect equipment or the grounded circuit of a wiring system to grounding electrode(s). This conductor is not intended to be a current carrying conductor except in fault conditions. The green wire (domestic), green with yellow stripe wire (international); or, the conduit or raceway are grounding conductors.

Grounding electrode conductor: The conductor used to connect the grounding electrode (NEC 250-81) to the equipment grounding conductor and/or to the grounded conductor of the circuit at the service equipment or at the source of a separately derived system.

Premises wiring: Interior and exterior wiring, including power, lighting, control, and signal circuit wiring together with all its associated hardware, fittings, and wiring devices, permanently or temporarily installed, which extends from the service point of utility conductors or source of a separately derived system to the outlet(s). Such wiring does not include wiring internal to appliances, fixtures, motors, controllers, motor control centers, and similar equipment.

Raceway: An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted by the NEC.

Separately derived system: See NEC 250-5(d) and NEC 250-26.

Isolation transformer: A transformer having electrical insulation and possibly electrostatic shielding between its windings such that it can provide isolation between parts of the system in which it is used.

Power distribution unit (PDU): A device, usually isolation transformer based, equipped with input and output circuit breakers, output receptacles or cables together with associated control and signal circuits. Such devices are often safety agency listed as electronic computer/information technology equipment or part of such a system.

Terra: French term meaning earth or ground. Used in international descriptions of power distribution systems.

References:

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