FAQ about Drives Technology

service & SUPPORT

Power supply systems

SIEMENS

MICROMASTER 4
SINAMICS G120

ID: 25220071

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ID: 25220071

Table of Contents

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http://support.automation.siemens.com/WW/view/en/25220071

Article ID: 25220071

1 Fundamentals

IEC 60364

Most standard power supply types found in the world fall into three categories. These categories relate to the International standard in IEC 60364.

IEC 60364 distinguishes between the three different earthing arrangements TN, TT and IT.

Characteristic features of systems are treatment of the relation between system and earth and also the relation between the exposed electrical parts of the system and earth.

1.1 Explanation of the concepts

The supply codes TN, TT and IT are detailed in IEC 60364, and are used to differentiate between different earthing arrangements.

The first letter signifies the connection between earth and the supply:

T direct connection of a point with earth

I no point is connected with earth (isolated), except perhaps via a high impedance.

The second letter signifies the connection between earth and the electrical device being supplied:

T direct connection to earth, independent of any other earth connection in the electrical supply system.

N connection to earth via the supply network.

The third and fourth letters signifies the location of the earth conductor:

S neutral and earth are separate

C neutral and earth are combined into a single conductor

Article ID: 25220071

1.2 What is earth?

Before discussing power supply types it is important to understand the difference between protective earth (PE) and functional earth.

In a general electrical supply system the earth or ground defines the potential of the conductors relative to the Earth's conductive surface. The way in which the earth is connected in the supply system has implications for the safety and electromagnetic compatibility (EMC) of the power supply.

1.2.1 Are protective earth (PE) & functional earth the same?

PE* and functional earth (equipment earth R_A) have the same function; however, as earth connection they have different functions.

The equipment earth R_A – although it also provides protection against electric shock - also fulfills another purpose. When the equipment is operated, the equipment earth can conduct current.

For drive inverters, the chassis connections are used both as PE as well as equipment earth.

* Additional information on the abbreviations is provided in the Chapter "Appendix"

Article ID: 25220071

2 Power supply systems

There are different line supply systems for the various line supply systems - e.g. 1-ph. 230V AC, 3-ph. 230V AC, 3-ph. 400V AC - and in turn these have various deviations and exceptions from the standard. In the subsequent text, this is the reason that only a 3-ph. 400V AC line supply is discussed.

For MICROMASTER 4 and SINAMICS G110 / G120 the following applies:

- The drive inverters can be operated on all three line supply systems (TN, TT, IT) - more detailed information is provided in the following description.
- Only permanently connected line supply connections are permitted.
- Drive inverters must always be earthed - both through the cable as well as through the frame/chassis.
- Every drive inverter must be separately fused as the fuses are used in this case as cable protection.
- Only type B r.c.c.b's (residual-current circuit breaker) may be used (one r.c.c.b. for each drive inverter)

Article ID: 25220071

2.1 TN - systems

In a TN line supply system, all frames/chassis of electrical equipment must be connected to the earthed point of the line supply (= functional earth, e.g. the neutral point of the transformer supply or the generator) via a PE with the PEN.

The neutral point of the transformer or generator must be earthed.

The PE or PEN must either be earthed at the transformer (generator) itself or earthed in close proximity.

The potential of PE or PEN should, under fault conditions, only deviate the smallest possible amount from the earth potential.

The following may be used as protective devices,

- Overcurrent protective devices
- Fault current protective devices (r.c.c.b.) may only be used in TN-S systems

In the event of short circuits to exposed conductive parts of negligible impedance, protective tripping via a protective device must be initiated.

- Within 0.2 sec. for socket outlet circuits (mobile equipment) up to 35 A
- Within 0.5 sec. for all other circuits (e.g. Inverter)

The following trip condition needs to be fulfilled (also for determining the maximum supply cable length):

$$\mathbf{Z_S \leq U_D / I_A}$$

Z_S = Impedance of the fault loop

U_D = nominal voltage to earth

I_A Tripping current (= current at which automatic tripping of the protective devices is initiated within the mentioned time. When using ELCB, I_A will be the rated fault current $I_{\Delta N}$)

There are three types of TN system depending on the arrangement of the neutral and protective conductors.

TN-S-System; TN-C-System; TN-C-S-System

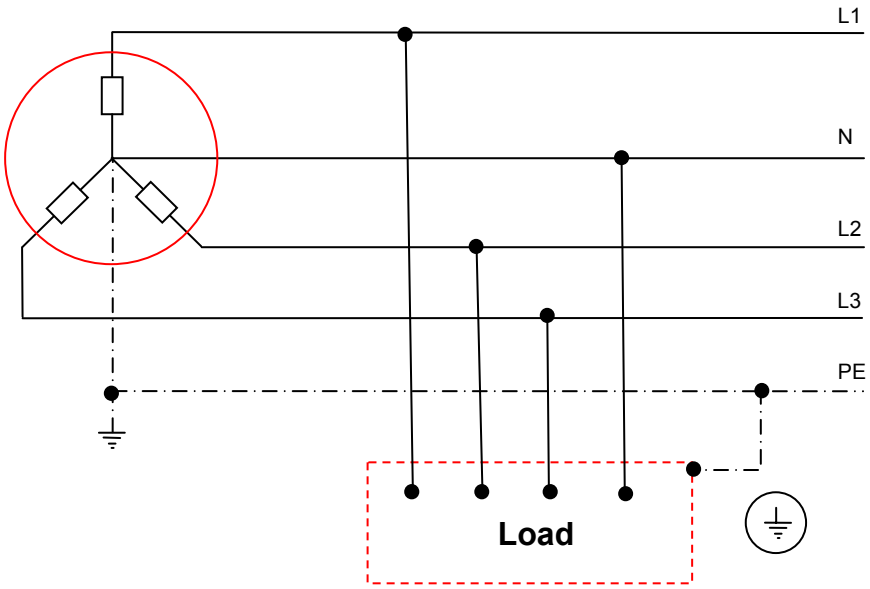
Article ID: 25220071

2.1.1 TN-S-systems

The following applies for this line supply system:

(Please refer to chapter “PEN-conductor”)

- Separate neutral- (N) and protective earth- conductors (PE) in the entire system.
- PE and Neutral are bonded at the star point.
- Cable cross-sections ≤ 6 mm² for Cu; ≤10 mm² for Al.
- Protected using overcurrent protective devices



Information regarding drive inverter operation

This line supply system is generally used for domestic households; this is the reason that it is hardly used for drive inverter applications.

Article ID: 25220071

2.1.2 TN-C-systems

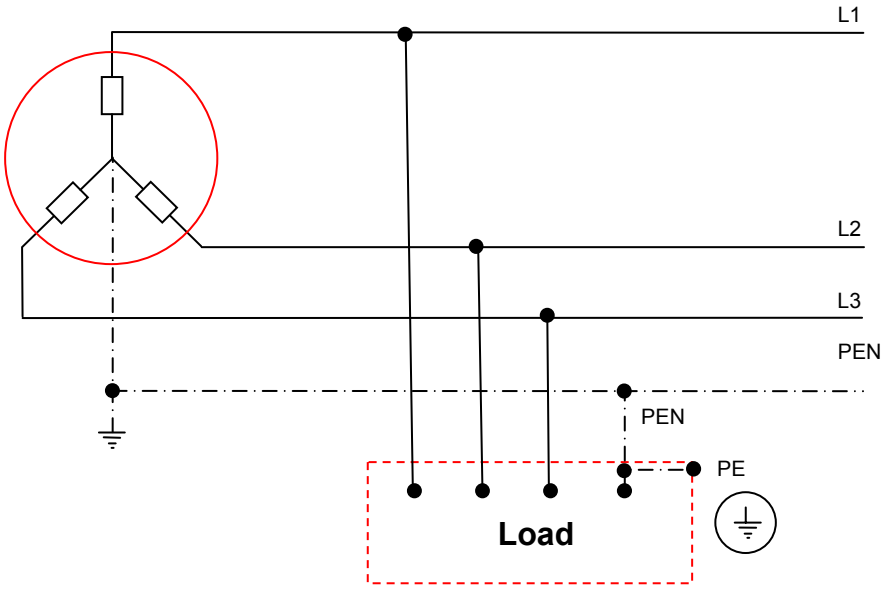
The following applies for this line supply system:

(also refer to the Chapter "PEN conductors")

- Neutral conductors (N) and protective conductor functions can be combined in the form of a single cable - the PEN - in the complete line supply system.
- Outer (phase cables) that can move must always have a PE
- If a fault condition develops, then current can flow in this conductor - even if there is no earth fault.

Further, the following conditions must be fulfilled.

- cable cross-sections ≥ 10 mm² for Cu; ≥ 16 mm² for Al.
- protected using overcurrent protective equipment and devices
- permanently routed cables



Information regarding drive inverter operation

Generally, drive inverters are operated on this line supply system (or in the TN-C-S line supply system).

It is absolutely essential that there is a good earth connection to the drive inverter frame/chassis, mounting point, cable shields etc.

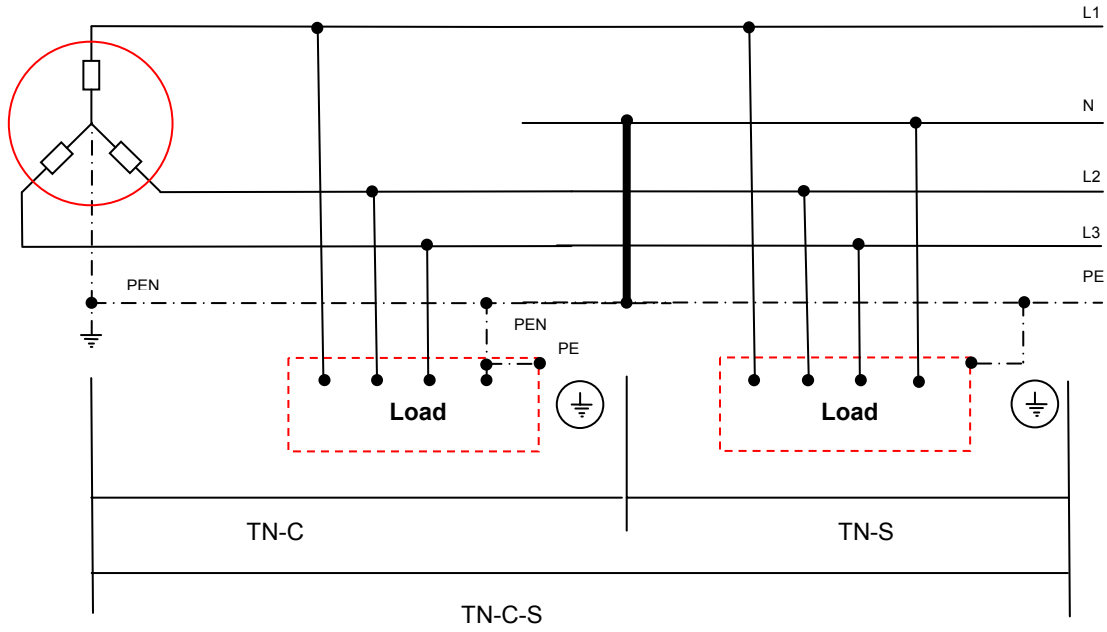
Article ID: 25220071

2.1.3 TN-C-S systems

In one part of the system, the functions of the neutral conductor and the protective earth conductor are combined in the PEN. In another part of the supply system, protective and neutral conductor (PE & N) are routed as separate cable. This supply system type is broadly established in the field (TN-C in the area of large conductor cross-sections, TN-S in the area of small conductor cross-sections)

Concerning the separation note the following:

- Behind the separations point of the PEN-conductors interconnection of the neutral and protective earth conductor is not permissible.
- Separate terminals or busses must be provided.



Information regarding drive inverter operation

Generally, drive inverters are operated in this line supply system (or in the TN-C line supply system).

It is absolutely essential that there is a good earth connection to the drive inverter frame/chassis, mounting point, cable shields etc.

Article ID: 25220071

2.2 TT systems

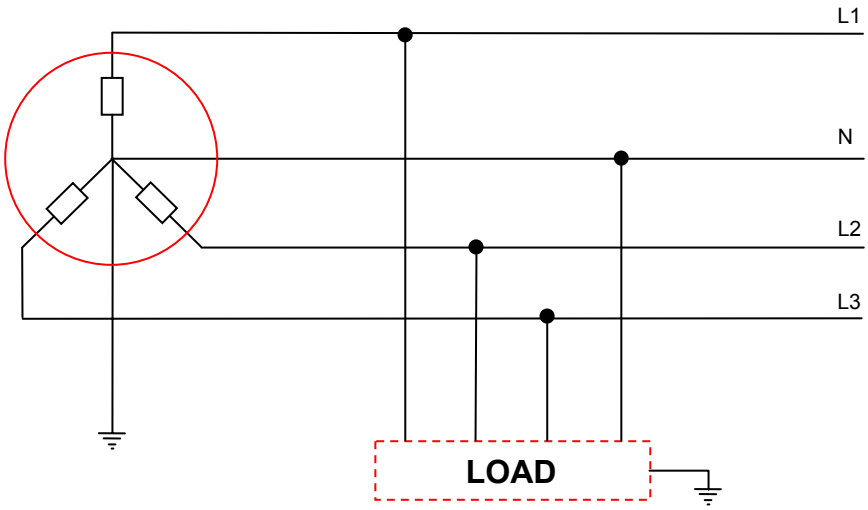
In the TT line supply system, it is not absolutely necessary that the protective conductor is also routed. The pieces of electrical equipment are connected to earth (R_A) in groups or together, independently of the neutral point earth (R_B) through a protective conductor. All equipment chassis - that are protected using a common fault current or overcurrent protective device - must also be connected to a common earthing system. The same applies at the same time for all equipment chassis that can be touched.

The neutral point of the transformer or generator must be earthed.

The most important feature in a TT line system is that when a fault situation develops, the fault current can flow back to the power source through earth - if required also through metallic components (chassis, mounting plate etc.). Generally, the fault current flowing through earth itself is significantly smaller than a short-circuit current in the TN line supply system. This is the reason that trips (when the equipment is shut down) with overcurrent protective devices are always associated with problems.

The following can be used as protective equipment and devices,

- Overcurrent protective devices
- Fault current protective devices (r.c.c.b.'s)



Information regarding drive inverter operation

Only drive inverters without filter may be connected to TT supply systems.

It must be carefully ensured that there is a good earth connection to the drive inverter frame, mounting point, cable shields etc.

Article ID: 25220071

2.3 IT supply systems

IT supply systems are generally isolated with respect to earth. Neither a phase conductor nor a neutral point may be directly earthed. However, IT supply systems may be earthed through a sufficiently high impedance.

There are IT supply systems with and without neutral conductor (N).

IT supply systems are predominantly used in applications that demand a high degree of operational, accident and fire safety.

For TN or TT supply systems, when a fault situation occurs then there is an automatic trip; on the other hand, for an IT supply system, when a fault develops, then the equipment can continue to be operated for some time.

When the first fault occurs in a three-phase system, all of the equipment chassis, protective conductors, potential bonding conductors and earthed, connected to one another assume the potential of the phase conductor with the fault. The two phase conductors that do not have a fault assume the phase voltage with respect to earth.

All of the chassis and external conductive parts that are connected with one another do not have a high touch voltage. This is the reason that a trip is not required; only an optical and/or acoustic signal that flags the fault (however, it goes without saying that the fault should be removed as quickly as possible).

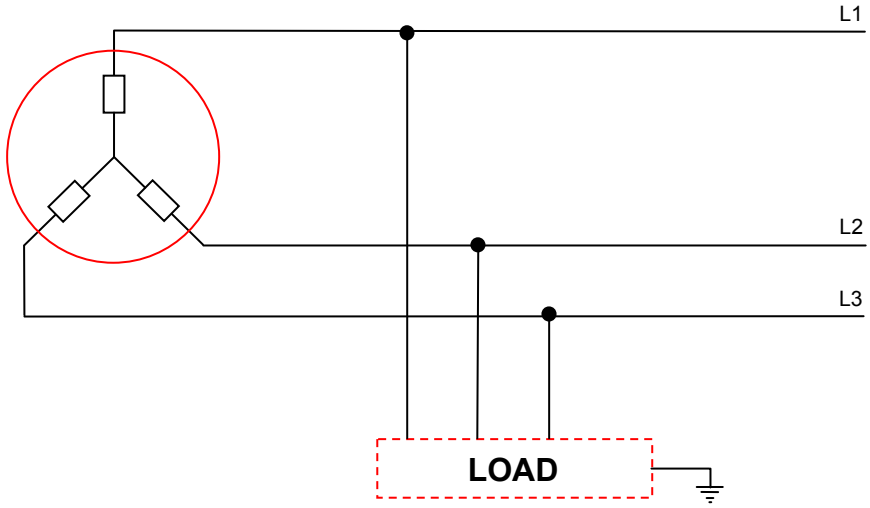
If, during operation with the first fault, a second fault occurs that is electrically unfavorable with respect to the first fault, then the equipment must be automatically tripped (shut down).

In a fault situation - i.e. earth fault - the insulation between the conductors at a certain potential and the local earth breaks down. This means that the local equipment earth assumes a certain potential.

The following may be used as monitoring and protective devices,

- Insulation monitoring equipment and devices (IMD)
- Equipment to identify insulation faults
- Overcurrent protective devices
- Fault current protective devices (r.c.c.b.'s)

Article ID: 25220071



2.3.1 IT networks and inverters

The following always applies:

Filters and drive inverters are designed for operation in an earthed line supply system. When operated with IT supply systems it is crucial that the drive application is very carefully engineered.

From the very mechanical design, the filter and the drive inverter are at a certain potential - i.e. discharge (leakage) currents flow with respect to earth. These discharge (leakage) currents have a negative impact on insulation monitoring equipment and devices.

Further, a fault current that flows can trigger undesirable operating states of the drive inverter - e.g. can cause a fault (earth fault) at the drive inverter output that then trips the drive inverter with an overcurrent fault.

Therefore, when operating drive inverters in IT supply systems:

- Both the filter as well as also the inverter with integrated filters may not be used in IT supply systems

- All non-filtered 400 V and 575 V MICROMASTER and SINAMICS G120 drive inverters can be connected to IT supply systems; however under the clear assumption that the following measures are carefully implemented:

- When connecting a MICROMASTER 4 to an IT supply system, the neutral point capacitor (Y capacitor) must be removed – removal instructions are provided in the Operating Instructions.

- For G120, it is not necessary to remove the neutral point capacitor, as it is not connected to PE.

- When operating the drive inverter on an IT supply system, an output reactor should be used to limit the high frequency circulating currents - that can flow in the case of an earth fault. This is necessary in order to protect the output components of the inverter from possible damage.

Comments regarding SINAMICS G110

Similar applies to SINAMICS G110.

For some SINAMICS G110 drive units it is not possible to remove the Y capacitor. Although it can be used in IT supply systems it has some associated problems (insulation monitoring equipment and devices are disturbed as a result of the leakage (discharge) currents, trip with overcurrent fault message when an earth fault develops at the drive inverter output).

Information on this subject is provided in the Operating Instructions

Article ID: 25220071

3 Appendix

3.1 Further letters in connection with the power supply

L1; L2; L3;	Power supply conductor
N	Neutral conductor

3.1.1 Functional earth R_B

The functional earth R_B - also known as neutral point earth - is the central earthing point of the line supply at the transformer (generator). The three phase conductors, the neutral conductor and the protective conductor at earth potential are all connected here (the total earthing resistance of the functional earth R_B may be a max. 2 Ohm).

3.2 PE - Protective conductors

PE = **P**rotective **E**arth

Protective conductor connections of outgoing cables must be accessible, protected against accidental loosening and individually detachable.

Connections for outgoing PE-conductors must be so arranged or marked that the associated circuit is clearly visible.

If one protective conductor is used jointly for several circuits, the cross-section of this conductor must minimal correspond to the largest phase conductor.

Types of cables etc. suitable for use as protective conductors:

- Conductor in multi-core cables
- Insulated and bare conductors under a common sheeting (e.g. in wiring conduits or ducts) with phase and neutral conductor
- Fixed bare or isolated conductors
- Metal coverings such as sheaths, shields and concentric conductors of certain types of cables.
- Metal tubes or other metal shielding for cables and wires (not permitted for us as PEN conductors)
- Profile sections or mounting bars made of Cu, Al, or steel.

3.3 PEN - conductor

PEN - conductors combine the functions of PE (protective-) and N (neutral-) conductor.

PEN - conductors can only be provided in TN-C and TN-C-S systems.

To avoid leakage currents, the PEN conductor must be insulated for the highest voltage that is expected; the insulation is not required within switchgear panels.

Profile sections may be used as PEN if they are made of Cu or Al and if terminals are mounted on it, but no equipment.

Any number of PEN, PE and N conductors can be connected to a PEN-bar, in any sequence.

Switching of PEN is not permissible (protective devices in is not permissible)

3.4 Protection against indirect contact

This means protection of persons, livestock, and property against hazards which may arise in the event of faults to frame doe to contact with exposed conductive parts or extraneous conductive parts.

Protection against indirect contact is - regardless of the voltage level – required for all electrical equipment and systems.

This protection can be achieved through measures that are generally applied - such as protection using automatic shutdown [trip] (e.g. fuses) (additional measures; protective insulation, safety extra low voltage, safe separation, functional extra-low voltage; these are generally limited to specific applications).

Article ID: 25220071

The following applies for MICROMASTER 4 and SINAMICS G110 / G120:

Fuses / circuit-breakers

Use suitable circuit-breakers / fuses with the rated currents specified in the documentation.

Residual current circuit-breakers (r.c.c.b.'s)

For drive inverters, frame sizes A to F, type B residual current circuit-breakers may be used (machines with a three-phase power supply, equipped with EMC filters, may not be connected to the line supply through a residual current circuit-breaker).

Exception for SINAMICS G110:

If the SINAMICS G110 drive inverter is connected to single-phase line supply with earthed neutral conductor, then a type A r.c.c.b is permissible.

- r.c.c.b. = residual current circuit-breaker
  - type A, 30mA
  - type B, 300mA

More detailed information is found in the respective operating instructions.

3.5 Conductor sizing

IEC 60364-5-54 provides a guide on how to correctly dimension PE conductors:

<table>
<tr><td rowspan="2"></td><td rowspan="2">c.s.a of phase conductors (mm^2)</td><td rowspan="2">Minimum c.s.a. of PE conductor (mm^2)</td><td colspan="2">Minimum c.s.a. of PEN conductor (mm^2)</td></tr>
<tr><td>Copper</td><td>Aluminium</td></tr>
<tr><td rowspan="5">Simplified Method</td><td><16mm^2</td><td>See note 1</td><td>See note 2</td><td rowspan="2">See note 2</td></tr>
<tr><td>16 – 25 mm^2</td><td rowspan="2">16 mm^2</td><td rowspan="2">16 mm^2</td></tr>
<tr><td>25 – 35 mm^2</td><td rowspan="2">25 mm^2</td></tr>
<tr><td>35 – 50 mm^2</td><td rowspan="2">Phase conductor c.s.a. /2</td><td rowspan="2">Phase conductor c.s.a. /2</td></tr>
<tr><td>> 50 mm^2</td><td>Phase conductor c.s.a. /2</td></tr>
</table>

Note:

This simplified method can only be used if the PE/PEN conductor is of the same material as the line conductors.

c.s.a = cross sectional area

1. If the PE conductor is a separate cable from that of the phase conductors the minimum values below must be observed:
   - 2.5 mm^2 if the PE conductor is mechanically protected
   - 4 mm^2 if the PE conductor is not mechanically protected
2. For mechanical reasons the PEN conductor must have a c.s.a. not less than 10 mm^2 in copper and 16 mm^2 in aluminium

Note how, in the table above, the PEN conductor (a combined PE and Neutral conductor) when constructed from aluminium, the cable must be larger than a copper cable. This is because copper is a much better conductor than aluminium.

3.6 Internet links

This list is by no means complete and only provides a selection of appropriate sources.

	Topic	Title
\1\	FAQ ID:10035164	Operation with unearthed supplies
\2\	FAQ ID:23119516	How to remove Y capacitors from MM440/430 Frame Size D&E
\3\	Configuration Manual [INTRANET]	SINAMICS G130, G150, S120 Einbaugeräte, S120 Cabinet Modules, S150
\4\	International voltages and frequencies	Electrical Current Abroad World Electric Guide

3.7 History

Tabelle 3-1 History

Version	Date	Changes
V1.0	April 2007	First issue