HELP

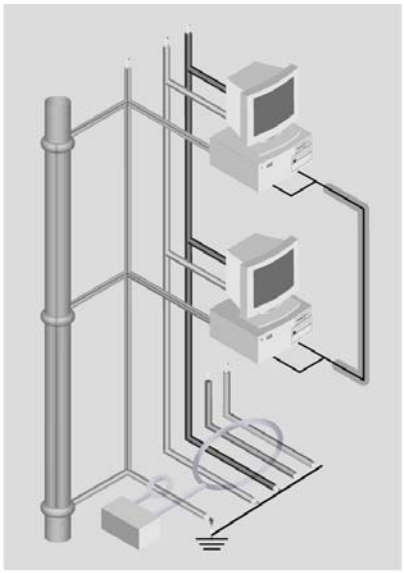
ON

CHECKING MAINS SYSTEMS

IN

TN-? SYSTEMS

To SUPPLY POWER
Building IT/Information Technology Systems



CORRECTPOWERINSTITUTE

The Institute for Correct Power and EMC/EMF

1-2006

PREFACE

The basis for the network analysis consists of the DIN VDE standards, and, here in particular, DIN VDE taking EMC into account

Communications systems in buildings DIN IEC, DIN VDE, DIN ETS, DIN EN publications

IBM planning manuals
IBM General Information Manual Installation Manual-Physical Planning (GC22-7072)
Guideline on Electrical Power for ADP Installations
IEE Wiring Regulations BS 7671
The wiring of premises SABA 0142:1993
Managing The Computer Power Environment
Electrical Code
Long term experience in Installation, maintenance and troubleshooting in
Computer rooms and electrical distribution networks.
Convert the electrical Network to TN-S-System

This script is based on the state of the art known to us.
It is not free from errors and is subject to constant changes resulting from the state of the art and new knowledge.
Please send changes, error corrections and other wishes to the publishers.

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Edition 1/2006

Why Check the Customer's Power Supply Network?

- ## INFORMATION PART

The electrical installations inside buildings have often grown inhomogeneously, depending on when systems were installed. Different electrical installation concepts planned for the protection of persons and objects may coexist. As a rule, electric power is distributed by several storey and subdistribution boards, and it is seldom possible to determine with ease how they have been assigned. Due to the existence of different distribution boards, there are different reference points, which can lead to disaster, especially in specific IT networking configurations.

Up to now, assumptions have been based on a THREE-PHASE SYSTEM in which the **N** conductor does not carry any current or the currents in the N conductor largely cancel each other out due to symmetrical loading of the phase conductors. Nowadays, however, the **THREE-PHASE AC SYSTEM** is used. In this system, **N** is used as the >retur**N** < conductor for the currents of the three phase conductors, which are no longer loaded symmetrically.
Due to mainly single-phase, non-linear loads (e.g. switched-load power supply units, electronic ballast units, etc.), the current on the >return**N**< conductor may amount to the total of all phase conductor currents.

Therefore, use of the **N** conductor in the dual function **PE** and **N = PEN** is predestined as a source of faults.

- ## Power Supply Possibilities (System Configurations)

  - ***5–conductor Systems (TN-S and TT Systems)***

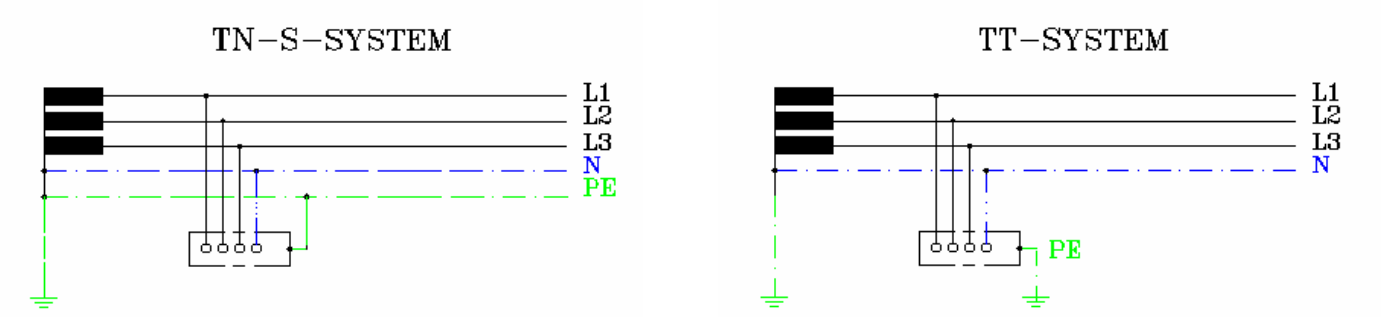


Figure 1 5-conductor Systems

In both systems, the star point **(N)** of the feeding source (transformer) is earthed (connection between **N** and **PE/PA!).**
As from the infeed point, these two conductors must be laid in an isolated fashion and must not be connected to one another again.

In the PE (protective earth) conductor, no operating current flows in a correctly installed TN-S/TT system, but only filter leakage currents.

- ***4–conductor Systems (TN-C and TN-C-S Systems)- Multiple-earthed Systems***

Although four-conductor systems largely conform to the valid VDE regulations, they are not justifiable (see EN 50310:2000, IEC 6036-5-548) from the EMC point of view, especially not for buildings containing information technology installations and systems (and where are these not installed nowadays?).

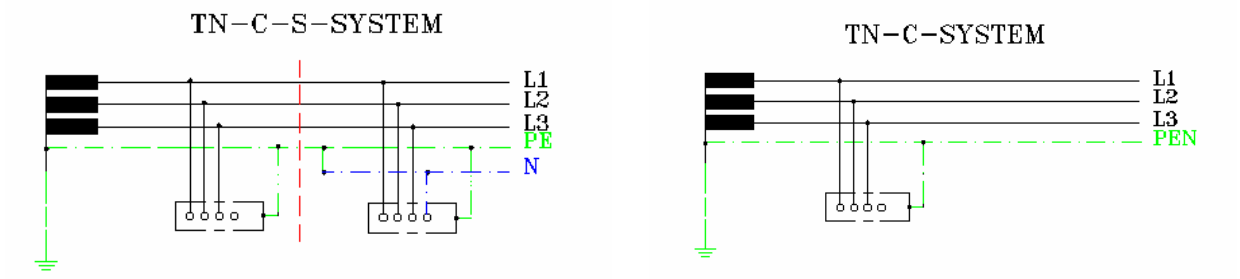


Figure 2 4-conductor Systems

Note on the use of Information Technology Systems

As <**N – Return**> and **PE** are combined in a **PEN** conductor, malfunctions and damage are pre-programmed.
It is possible to work with the system, but faults can be expected (caused by earth loops and operating currents in the PE conductor), for example workstation computer and system crashes, screen display flickering, printer faults, slowing down to standstill of data transfer along the data line, tripping of alarm systems and fire detectors, corrosion of pipes and earthing leads, from pipe corrosion to leaks, indeterminate faults and illogical response of electronic systems and devices, etc.

- ***Special IT System Configuration***

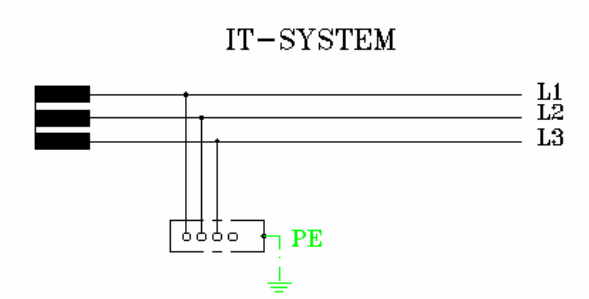


Figure 3 IT System

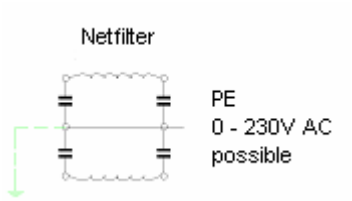


Figure 4 Mains Filter

This system configuration is not suitable for systems containing networked IT systems because the capacitors of the mains filters are switched against the **PE**.
The feed-in network has no point that is defined with respect to the earthing system.

- ***Multiple Infeeds***

In the TN system, the **N** conductor is connected **ONCE ONLY** in the entire system to the **EB (equippotential bonding bar)/earth electrode**.
This also applies if there are several infeed points.

DIN VDE 0100-300 312.2.1 IEC 364-3:
In TN-S systems, ONE point is earthed directly, and the devices in the electrical system must be connected to this point by means of PE conductors.

Transformers, motor generators and uninterruptible power supplies (UPS) can be looked upon as being infeed points.
Here, all N conductors are permanently connected to one another and are connected to the *CEP* (*C*entral *Ea*rthing *P*oint) ONCE ONLY in the entire system.
This connection should be made at the point of the highest expected short-circuit/earth fault current, but so that measurement/monitoring at this point can take place safely.

Remote infeed points are not connected to one another.
Each of these points is a self-contained TN-S system and is connected only to existing joint EBs/earth electrodes.
Connections between the N conductors of different/separate networks are not permitted.

UPS Systems

(Uninterruptible power supply UPS)

Three-phase mains connection L1, L2, L3, (PE)!
- Generally no N is needed here!
Bypass three-phase AC, L1, L2 .L3, N, PE
- Here, the N input is permanently connected to the N output.

In the UPS, the neutral conductor **(N)** and the protective earth **(PE)** **MUST NOT BE JUMPERED**.

The one-phase version must be connected analogously.
The **N** conductor of the output line must be connected permanently to the network's N conductor as otherwise floating of the N will occur.
(star point shift)
(e.g. L=125 VAC N=125 VAC to PE (earth))

- ***Important!***
  There are now UPS systems on the market that do not have a bypass circuit, though. These can consist of an insulated setup by the interconnection of transformers.
  The outputs of such UPS systems must then be considered as being self-contained systems. Here, the outgoing **N** is connected **once** to the PE/EB.

- ***Prerequisite for Installation and Operation of Electronic Systems in line with EMC Requirements***

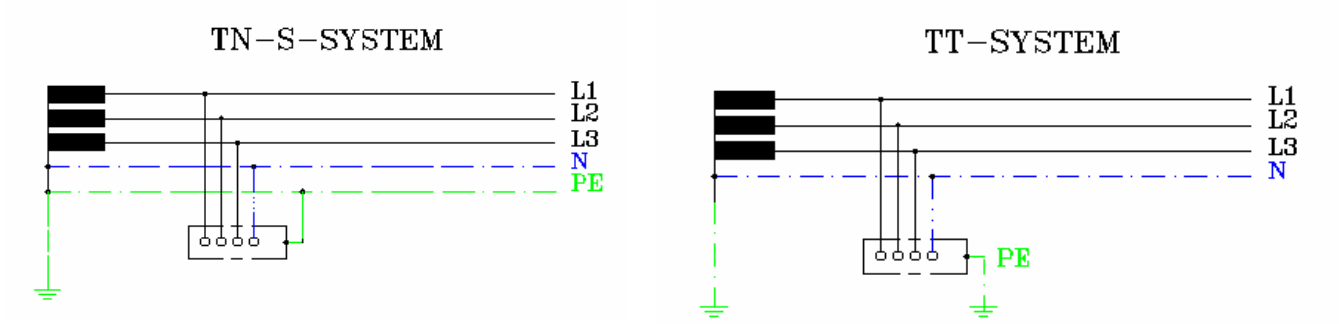


Figure 4 EMC–Compatible System Configurations

- **Consistent establishment of a TN-S/TT system in accordance with VDE 0100 with separate neutral and PE conductors in the entire system as from the infeed point**
- **Electrical connection between the neutral conductor (N) and the PE conductor (PE) at only one point**
- **e.g. (CEP) low-voltage main distribution board busbar**
- **In smaller systems at the transformer star point**
- **In the service entrance box (PE)N only one connection to the EB bar**
- **The earthing point (CEP) must be connected directly to the earth electrode**

In the TT system, the earthing resistance must be better (→ less resistance) than required by the VDE regulations for deactivating the current-actuated earth fault circuit-breaker (RCD residual current device), e.g. maximum permitted earthing resistance in accordance with DIN VDE 0664 in the case of

Rated fault current of circuit-breaker	R_E at U_B 25V /Ω	R_E at U_B 50V /Ω
10 mA	=/< 2500	=/< 5000
30 mA	=/< 833	=/< 1666
100 mA	=/< 250	=/< 500
300 mA	=/< 83	=/< 166
500 mA	=/< 50	=/< 100

If the earth electrode is in line with specifications and standards, but if its resistance is too high, earth potential seeks to balance itself out through all conductive parts (IT data lines and signalling lines).
This produces undefinable faults!!!

BS 7671 (British Standard): it is recommended that the resistance should not exceed a value of 220 Ohm.

In all systems, the PE must be laid radially from every main EB bar to every distribution board.

- **Measurements**

IMPORTANT!
The safety regulations must always be observed whenever performing measurements and checking work.
Use always only safe tools.

Beforehand, adequately familiarise yourself with how to handle the measuring instruments.
Currents (A) must be measured without interruption using a current probe.

A current probe with a resolution of 0.01A or better and an evaluation (display) unit (TRMS) must be used, e.g. current transformer probes with a 1V AC/1A AC output. The probe can be connected to any measuring instrument that has mV-AC measurement ranges and an input impedance of more than 10KOhm.
e.g.:

AC probe Type CV100	1:1 division ratio
AC probe Type CV35	1:1 division ratio
Flexible current transformer Type CA 120503 (AmpFlex)	1:10 division ratio

Make: Chauvin Arnoux
Plus multimeter, TRUE RMS or scope.

Use a current probe with a high resolution of two (or better three) decimal places, e.g. HIOKI 3281.
To be able to measure at poorly accessible points, use a small current probe with a large measurement opening, e.g. HIOKI 3280. Voltcraft Current Probe VC 120 resolution 0,001 A

If you suspect problems, check the following points by measuring the current:

- All leads connected to the **EB** bar (see Realisation Part Page 11, Figure 8)
- The differential currents through L1, L2, L3, N, (see Figure 5 – c)
- On the leads to the low-voltage main distribution board (see Figure 5)
- On the leads from the low-voltage main distribution board to the subdistribution boards (see Figure 5)
- On the leads to and from the service entrance box (see Page 11, Figure 8)

The sum of all currents flowing in a cable is zero.

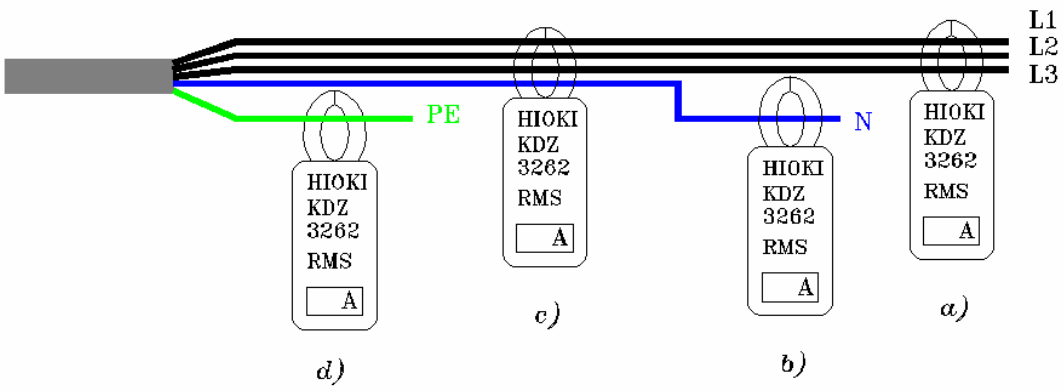


Figure 5 Measuring with a Current Probe

a)	L1 ,L2 ,L3 ,		x A
b)	N	-	y A
c)	L1 ,L2 ,L3 ,N ,	=	0 A
d)	PE / PA		

- **Resistance Measurements**

The current and voltage method has proven effective for measuring the earth contact resistance and other low-resistance parts of a system. A transformer with a 230V AC input supplies a voltage of 12V AC and the current, which can be switched by one or two incandescent bulbs, is limited.

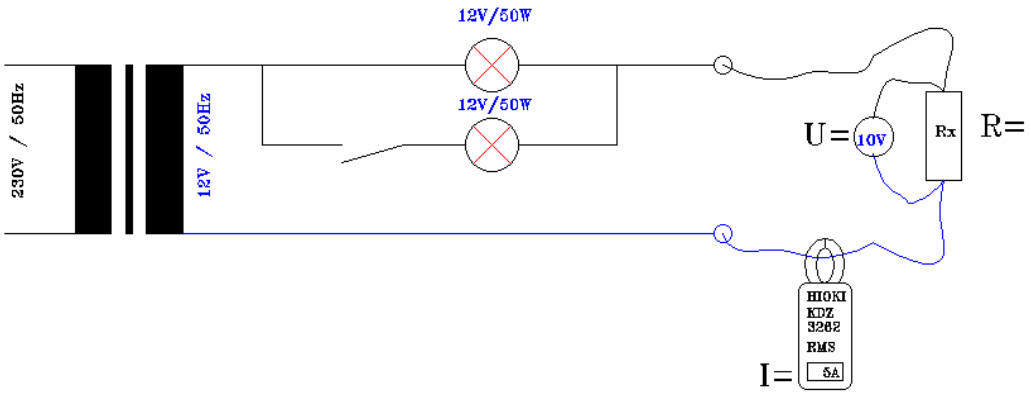


Figure 6 Determining Resistance by the Current and Voltage Measurement Method

R = U : I
R_x = 10V : 5A = 2Ohm
U = VAC at the two terminal points where the current I is fed in

- **Previous Experience**
- Functioning of the system is not limited, disturbed or destroyed if the following values are not exceeded. Currents up to 0.05A, measured with a current probe, if they have the sine-wave shape and no interference spikes, short-term changes, peak values or frequencies deviating from the mains frequency occur.

  Detailed measurements can be performed with an oscilloscope and corresponding current transformer probes.
  Long-term recordings are possible with the Dranetz, a measuring PC or a BMI.
  The measurement system from POWER MEASUREMENT, for example, has proven to be a low-cost alternative. This system can be used for permanent mains system monitoring/analysis. With current probes, a visual check and adequate experience, mains system faults can already be detected after a short time.

  The test points in/on housings and cable inlets must be installed and documented so that safe and no-problem checking/measurement is possible at all times. Measured values must be noted down in the proximity of the measurement point (adhesive label containing details of the measured value and date) to enable fast comparison with other measurements.

When performing all checks, always observe the following points:

- Check cables for extreme heat development - Insulation shows deformation
- Cable cross-section not adapted to the **N** conductor current - (reduced!)
- The basic colours of terminal connections have changed.

REALISATION PART

Refer to the attachment entitled “Current Distribution” for details of test points

IMPORTANT!
It is imperative to observe all safety regulations when working and performing measurements on live systems.
Safety always has priority.
Measure currents without interruption using a current probe.

1. Transformer

a) Is the **N** conductor (neutral point, star point; here, there is no **PEN**) connected directly to the **EB**/earth electrode? *Y - N*

b) Current in this connection __.__*A*

If there is a connection here, there must be NO further connection in the TN–S system!!!

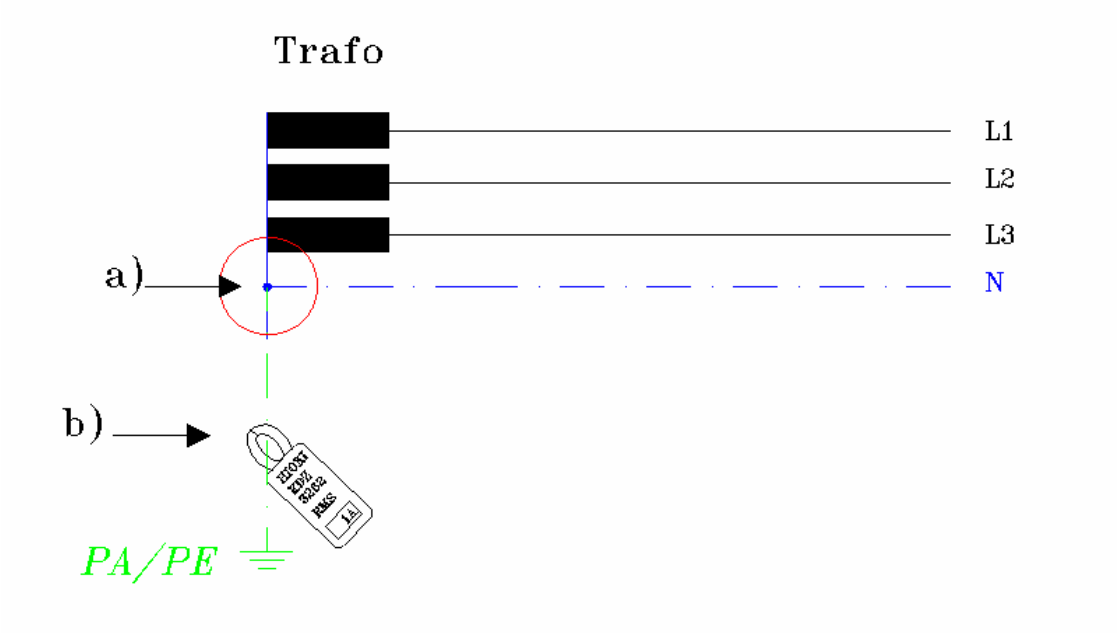


Figure 7 Measurements on the Transformer

2. *Service Entrance Box*

a) Differential current on the incoming line to the service entrance box through L1, L2, L3, (PE) N __.__A

b) Differential current on the outgoing line from the service entrance box through L1, L2, L3, N __.__A

c) Current on the connection of the (PE) N of the service entrance box to the EB bar (TN system only!) __.__A

d) Current from the EB bar to the earth electrode __.__A

In the TN–S system, there is one connection only between PE and N (PEN)

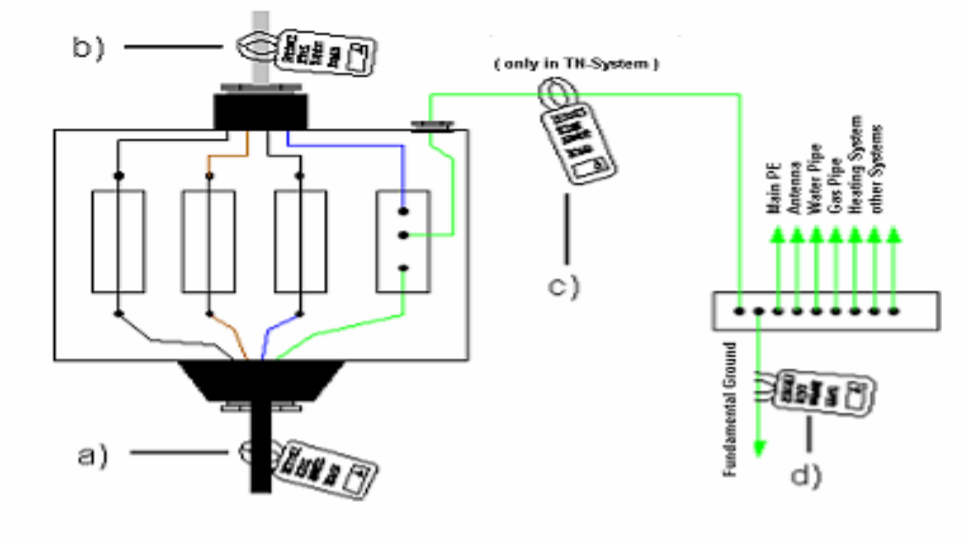


Figure 8 Measurements on the Service Entrance Box in the TN System

In the TT system there are no connections between N and PE

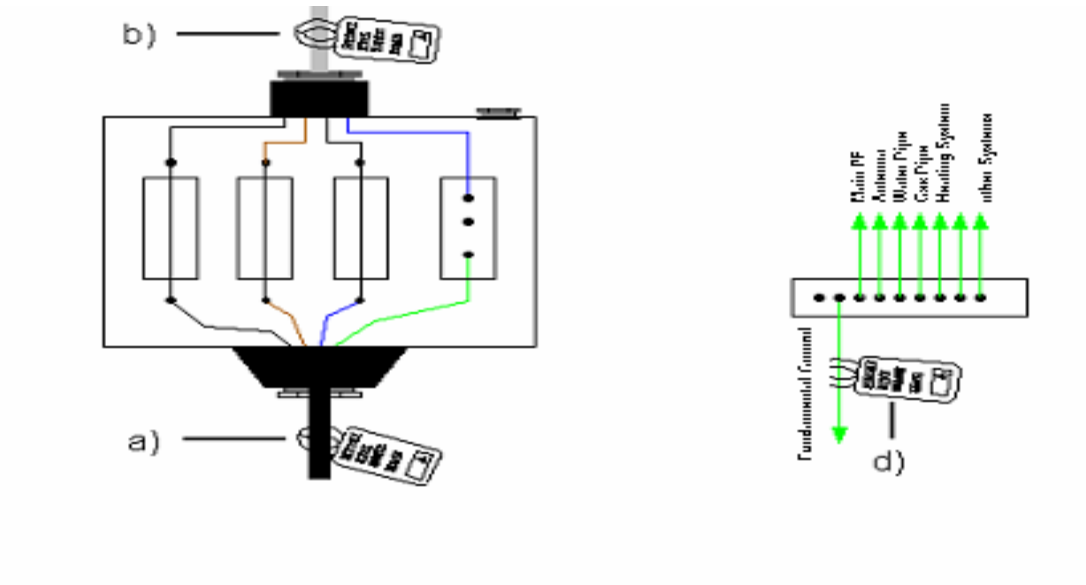
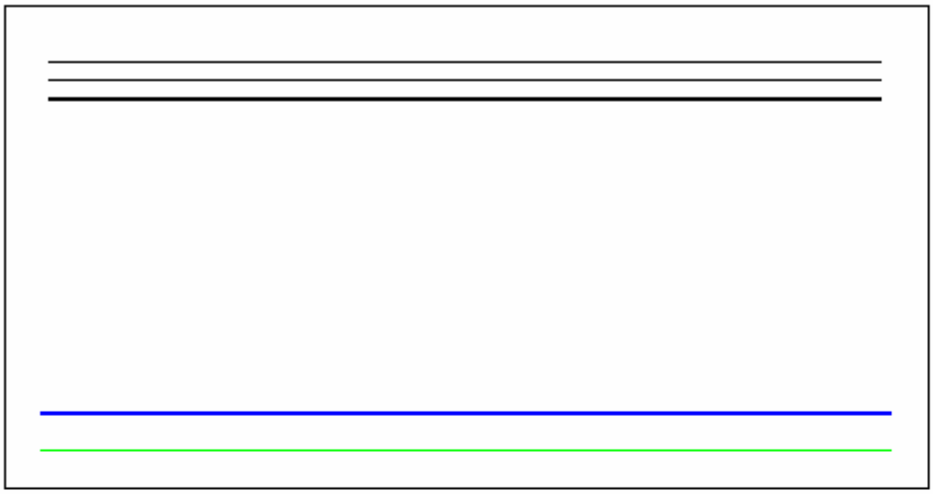
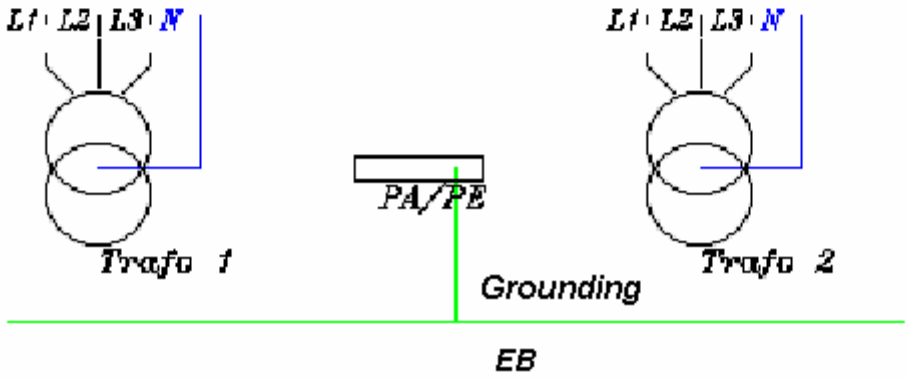


Figure 8a Measurements on the Service Entrance Box in the TT system

3. *Low-Voltage Main Distribution Board*

Current Supply to the Low-Voltage Main Distribution Board





Complete the cable layout:

Figure 9 Structure of the Power Supply (Lines from the Transformer to the Low-Voltage Main Distribution Board)

4 wires in the cable	L1, L2, L3, N	*Y – N*
or		
5 wires in the cable	L1, L2, L3. N. PE	*Y – N*
Single wires		*Y – N*
Number of wires :	L1 x _____ L2 x _____ L3 x _____ **N** x _____ **PE** x _____	
Differential current through	**L1, L2 ,L3,**	___.___*A*
Current on	**N**	___.___*A*
Differential current through	**L1. L2 .L3 . N**	___.___*A*
Current on	***PE***	___.___*A*

Equipotential bonding bar (EB bar) available in the building *Y - N*
Current in the connection from the EB bar to the earthing system ___,___*A*
Current in the lines from/to the EB bar *(see Sheet 10 d))*

Cable Designation	I/A	Cable Designation	I/A

EB earthing resistance, capable of carrying load, current and voltage method _____Ω

EB earthing resistance, capable of carrying load, measured with measuring bridge _____Ω

EB bar in other distribution boards *Y - N*

As specified in VDE 0100, the N cross-section in the three-phase AC network must not be reduced!

All wires have the same cross-section. *Y - N*

*If the cross-section of **PEN** is reduced, you must check whether the switch-off conditions are met, taking into consideration the current load and including the thermal correction factor.*

Where and how is **N** or **PE** earthed?
(In the TN system PE/EB is connected once only to N!)
Just like a phase, the entire laid length of **N** is insulated.

4. *Distribution Board*

4.1. Three-Phase AC

	5 wires in the L1 .L2 .L3 .N .PE cable	*Y - N*
Current supply:	4 wires in the L1 .L2 .L2 .N cable	*Y - N*
	PE separate	*Y - N*
Differential current through	L1 .L2 .L3 .	__.___*A*
Current on	**N**	__.___*A*
Differential current through	L1 .L2 .L3 . N .	__.___*A*
Current on	***PE***	__.___*A*

4.2. One-Phase AC (often after UPS systems in the IT)

	3 wires in the L1 . N . PE cable	*Y - N*
Current supply	2 wires in the L1 . N cable	*Y - N*
	PE separate	*Y - N*
Differential current through	L1 . N .	__.___*A*
Current on	**N**	__.___*A*
Current on	***PE***	__.___*A*

4.3 Voltage Measurement

L1 – N	_____*V*
L2 – N	_____*V*
L3 – N	_____*V*
PE –N	_____*V*

C A U T I O N !

Voltage between **PE** and **N** in the distribution board. A large voltage difference is an indication of a fault between **N** and **PE** (defective neutral conductor terminals or excessive **N** load, 150Hz)
High currents can occur!

Is overvoltage protection available? Dehn, Phoenix, Betterman, etc.? *Y - N*

Does the connection consist of 3 poles? *Y - N*

Does the connection consist of 4 poles? *Y - N*

Where and how is/are the surge arrester(s) connected? *EB bar – earth electrode - N – PEN - PE*

Remarks:

5. UNINTERRUPTIBLE POWER SUPPLY

Is a UPS installed? *Y - N*
Make and type of UPS _____

5.1. INPUT; Supply Line:
One-phase AC or three-phase?
If one-phase AC, continue with Section 5.3.

5.1.a Main Supply Line to the UPS

	5 wires in the L1,L2,L3,N,PE cable	*Y - N*
or		
	4 wires in the L1,L2,L3,N cable	*Y - N*
	Differential current on this cable	__,___ *A*
	Plus PE separately	*Y - N*
	Current on PE	__,___*A*

*Where and how is **N** connected?*

5.1.b BYPASS Supply Line to the UPS

	5 wires in the L1,L2,L3,N,PE cable	*Y - N*
or		
	4 wires in the L1,L2,L3,N cable	*Y – N*
	Differential current on this cable	__,___ *A*
	PE separate	*Y - N*
	Current on this PE	__,___*A*

*Where and how is this **N** connected?*

5.2. OUTPUT:
Three-phase AC:
*If one-phase, then continue with **5.4***

Current supply from the UPS to the load

	5 wires in the L1,L2,L3,N,PE cable	*Y - N*
or		
	4 wires in the L1,L2,L3,N cable	*Y - N*
	Differential current on this cable	__,___ *A*
	Current on the PE	__,___ *A*

Check all N and PE terminals exactly.
There must be no bridge between N and PE anywhere in the UPS!!!

For such investigations, always consult the internal circuit diagrams of the systems.

5.3 INPUT

One-phase AC, permanently connected

5.3.a Current Supply to the UPS	3 wires in the L1,N,PE cable	*Y - N*
or		
5.3.b Current Supply to the UPS	2 wires in the L1,N cable	*Y - N*
	Differential current of this cable	__,___*A*
	Plus PE separate	*Y - N*
	Current on the PE	_,___*A*

5.4 OUTPUT

One-phase AC, permanently connected:

5.4.a Current supply from the UPS to the load

3 wires in the L1,N,PE cable	*Y – N*
Differential current of this cable	__,___*A*
Plus PE separate	*Y - N*
Current on the PE	__,___*A*

or

5.4.b Current supply from the UPS to the load

2 wires in the L1,N cable	*Y - N*
Differential current of this cable	__,___*A*
Plus PE separate	*Y - N*
Current on the PE	__,___*A*

5.5 Voltage Measurement:

If mains voltage absent at the input:

L - N	_____*VAC*
L - PE	_____*VAC*
N - PE	_____*VAC*

In the case of UPS systems with a 230V AC plug connection, **N** is seldom reliably defined. Thus, the behaviour of the UPS is undefined in relation to **N** during normal mains operation, active battery operation and in the bypass mode.

How and where N is wired in the UPS can only be determined by referring to the circuit diagram of the UPS.

In the TN-S system, N is connected once only to EB/earthing electrode and this is the infeed point. A UPS does not constitute electrical isolation because the incoming N is permanently connected to the outgoing N to prevent floating of N.

Consequently: in the UPS, N must not be connected to PE.

Trick circuits are repeatedly tried out!!!

IT SYSTEM ROOM DISTRIBUTION BOARD

6.1. Three-phase AC

Current supply:	5 wires in the L1 .L2 .L3 .N .PE cable	*Y - N*
	4 wires in the L1 .L2 .L2 .N cable	*Y - N*
	PE separate	*Y - N*
Differential current through	L1 .L2 .L3 .	__.___*A*
Current on	**N**	__.___*A*
Differential current through	L1 .L2 .L3 . N .	__.___*A*
Current on	***PE***	__.___*A*

6.2. One-Phase AC (often after UPS systems in the IT)

Current supply	3 wires in the L1 . N . PE cable	*Y - N*
	2 wires in the L1 . N cable	*Y - N*
	PE separate	*Y - N*
Differential current through	L1 . N .	__.___*A*
Current on	**N**	__.___*A*
Current on	***PE***	__.___*A*

6.3 Voltage Measurement

L1 – N	_____*V*
L2 – N	_____*V*
L3 – N	_____*V*
PE –N	_____*V*

Are current-actuated earth fault circuit-breakers installed? *Y - N*

What tripping range? ____*mA*

Differential current on the supply line to the earth fault circuit-breaker ____*mA*

Current along PE from the earth fault circuit-breaker's outgoing cable ____*mA*

Caused by the mains filters, high leakage currents can occur when new IT systems are switched on, but these are very low during operation.

Integrated overvoltage protection elements are an indication of suspected problems. Such overvoltage protection helps only against transient interference and not against overvoltages and star point shifts of the mains voltages.

A tripped current-actuated earth fault circuit-breaker is intolerable for an IT system. This problem does not occur when using the differential current monitor (RCDM).

Is EMERGENCY STOP integrated? *Y - N*

Is overvoltage protection or similar (incandescent bulbs) integrated? *Y - N*

Is there a current-actuated earth fault circuit-breaker/EMERGENCY STOP? *Y - N*

Electronic circuitry reacts sensitively to overvoltage? *Y - N*

(if problems are suspected, please copy this page several times)

7. MEASUREMENTS ON THE IT SYSTEM

On the assembled, operable system, with all cables connected

7.1. Differential Current along the Mains Supply Cable to the Housing, Printer or Monitor

Housing _____ __,___ *A*
Housing _____ __,___ *A*
Housing _____ __,___ *A*
Housing _____ __,___ *A*
Housing _____ __,___ *A*
Housing _____ __,___ *A*
Housing _____ __,___ *A*
Housing _____ __,___ *A*

7.2. Additional Cables on/to the System, e.g. Green/Yellow Earth Electrode/Equipotential Bonding Leads.

Cables from where to where with details of each cable's current

_____ __,___ *A*
_____ __,___ *A*
_____ __,___ *A*
_____ __,___ *A*
_____ __,___ *A*
_____ __,___ *A*
_____ __,___ *A*
_____ __,___ *A*

7.3. Current Measured from

Computer housing _____ to housing _____

Housing _____ to housing _____

For this purpose, an earthing strip is fitted from one housing to the other and the current through it is measured.

8. MEASUREMENTS ON DATA LINES

Currents on the cables from the computer to the screen workstations, printers, data acquisition devices and other connected devices.

8.1. Current on the Lines that leave the Computer

Cables: channel, Twinax, serial, parallel, coax, type 1, loop lines, modem cables, Ethernet, STP, UTP, etc.

Cable designation _____ __,___ *A*
Cable designation _____ __,___ *A*
Cable designation _____ __,___ *A*
Cable designation _____ __,___ *A*
Cable designation _____ __,___ *A*
Cable designation _____ __,___ *A*

No measurable current should flow along the mains cables of monitors and printers.
Please perform the corresponding measurements and record details of them.

These measurements have been carried out:

Date _____

Time _____

Customer name _____

Address _____

_____

_____

Persons present:

Name	Company	Signature
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____