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Comparison of Neutral Wire Distribution Options for Data Centers

White Paper 41

Version 1

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Executive summary

A typical electrical distribution topology used for critical applications involves using a backup generator and an Uninterruptible Power Supply (UPS) system to ensure the continuity of the power supply. When the main low voltage (LV) switchgear is equipped with a 4-pole transfer switch, questions arise as to what happens during a changeover. The UPS and the downstream loads switch from a TN grounding system to an ungrounded system and may experience some disturbances. This document discusses the potential power quality issues that can arise under this scenario and summarizes and compares different neutral wire distribution alternatives that avoid or minimize the risk of generating power disturbances that can cause interruptions or equipment malfunctions.

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Introduction

In data center applications, a TNC-based grounding system is not recommended because load current can flow in the protective earth (PE) conductor causing electromagnetic compatibility (EMC)-related disturbances such as grounding noise, loss of equipotentiality, voltage harmonic distortion, and a malfunctioning of sensitive equipment. The best practice recommended by low voltage installation standards (such as IEC60364) is to use a TNS grounding system for the low voltage (LV) distribution path in the data center building.

Two LV distribution topologies commonly exist today: the LV distribution in TNS with LV/LV isolation transformer (also known as a PDU transformer) and the LV distribution in TNS without LV/LV transformer commonly referred to as a remote power panel (RPP).

LV distribution in TNS with PDU transformer

The distribution with PDU transformer is used in North America where the three-phase UPS system operates at 480V with a downstream 480V/208V transformer used to supply the single-phase servers at 110V as shown in **Figure 1**. Using a Delta Wye PDU transformer, the distribution from the medium voltage/low voltage (MV/LV) transformer to the PDU transformer does not require a neutral conductor. This architecture is also used in some other locations outside of North America using International Electrotechnical Commission (IEC)-level voltages such as 400V/400V PDU transformers.

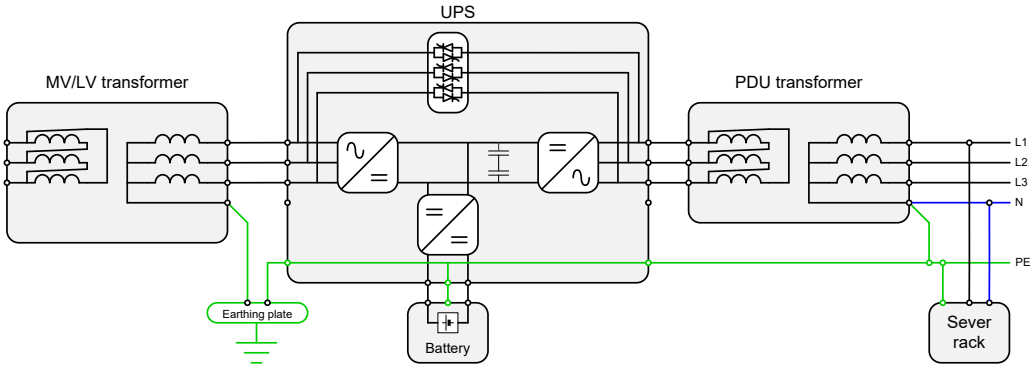


Figure 1

LV distribution in TNS with PDU transformer

LV distribution in TNS without PDU transformer

In IEC-based regions, there is only one LV voltage level. No LV/LV transformer is required as shown in **Figure 2**. Low voltage IEC-based three-phase UPSs operate at 380V to 415V and single-phase servers operate at 220 to 240V.

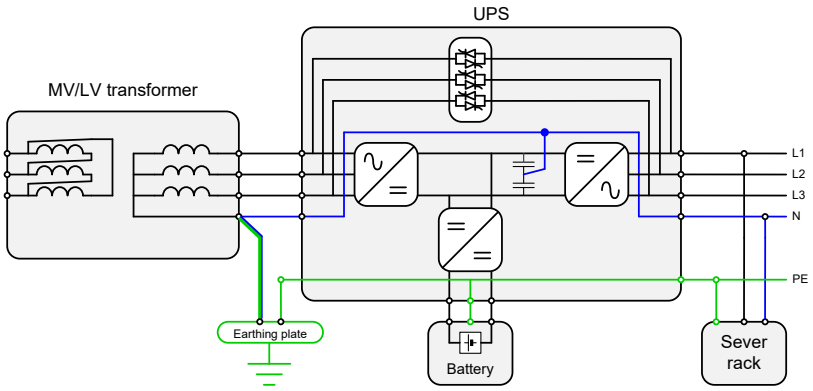


Figure 2

LV distribution in TNS without PDU transformer

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When no PDU transformer is used, the server's power supply unit (PSU) neutral reference to ground is made at the upstream source level (MV/LV transformer or LV generator). When local installation rules do not allow the use of a removable link for neutral disconnection, 4-pole circuit-breakers shall be used as shown in **Figure 3**.

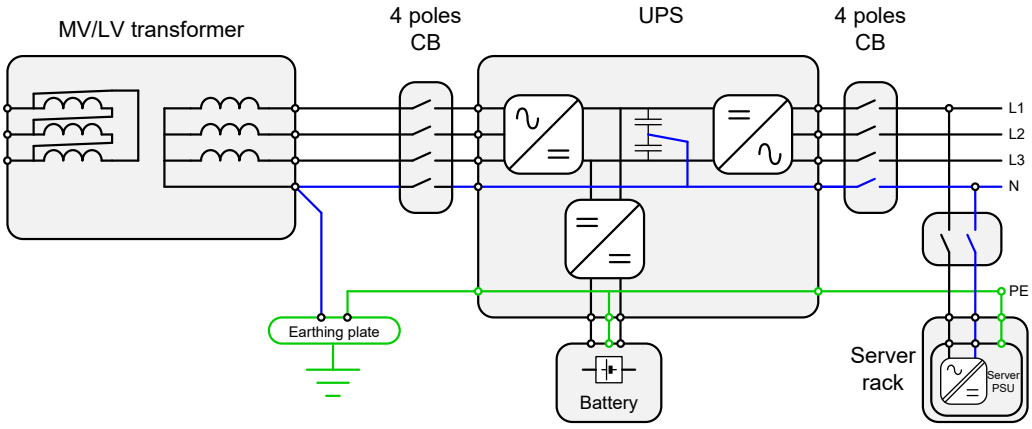


Figure 3

TNS distribution of a secured LV distribution for data center with 4-pole circuit breakers and no PDU transformer

When a 4-pole circuit breaker is opened upstream of the UPS, the UPS will operate ungrounded and the network downstream of the UPS could then possibly face some issues due to the loss of the neutral reference to earth. This could result in there being a lack of protection and expose the load to voltage and current transients. Note that given the trend in the United States (an ANSI-based region) of using 240V equipment with 415/240V distribution, some US data center architects may adopt LV distribution systems without PDU isolation transformers as is commonly done in Europe.

This white paper discusses the potential power disturbances caused by the loss of a neutral reference to ground and compares various solutions for avoiding or minimizing the impacts of these power disturbances in data centers.

Description of power transients

This section describes the types of power disturbances and their potential impact that are created when the neutral reference to ground is lost or when a TNC-S earthing system is used. Recommendations are also provided.

Transients resulting from disconnecting and re-energizing 4-pole circuit breakers (CBs) in a 4-wire system

A typical scenario where this happens involves the sequence of a transfer from one source to another using 4-pole circuit breakers (e.g. performing a test). In this scenario, a transient can occur both when the network is disconnected and re-energized. The power transient causes a common mode overvoltage (i.e., line-to-ground) that can last a few seconds and cause some common mode currents in the residual current devices (RCDs).

During disconnection, the energy stored in the cables upstream of the UPS are discharged into the earth through the network capacitance which includes the stray cable capacitance, UPS EMC filters, and the loads' EMC filters as shown in **Figure 4**. During this transient, the UPS neutral-to-ground voltage experiences a voltage peak that represents the charging of the network capacitance followed by a slow decrease (down to zero) that represents the discharge of the network capacitance through the network leakage resistance as shown in **Figure 5**. The UPS line-to-neutral output voltage is regulated without any power disturbances thanks to the UPS output inverter, but the UPS line-to-ground output voltage will experience the transient.

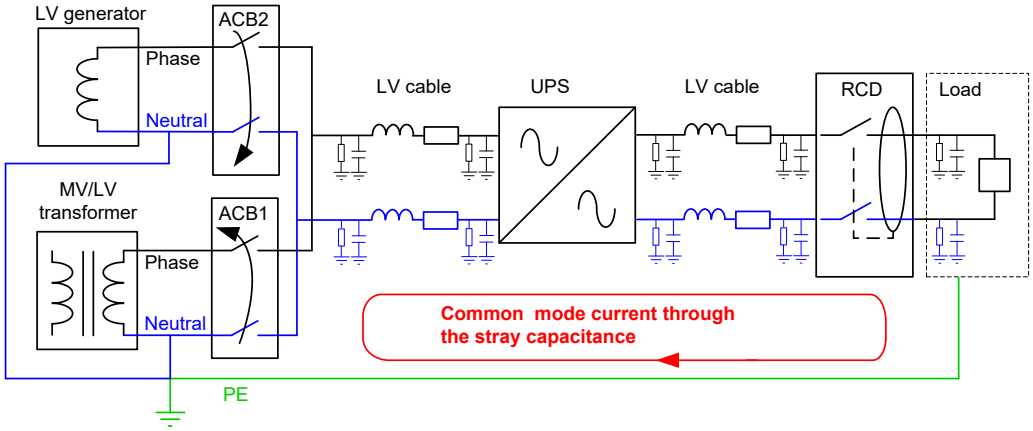


Figure 4

Common mode transient during the opening of the 4-pole CB upstream of the UPS

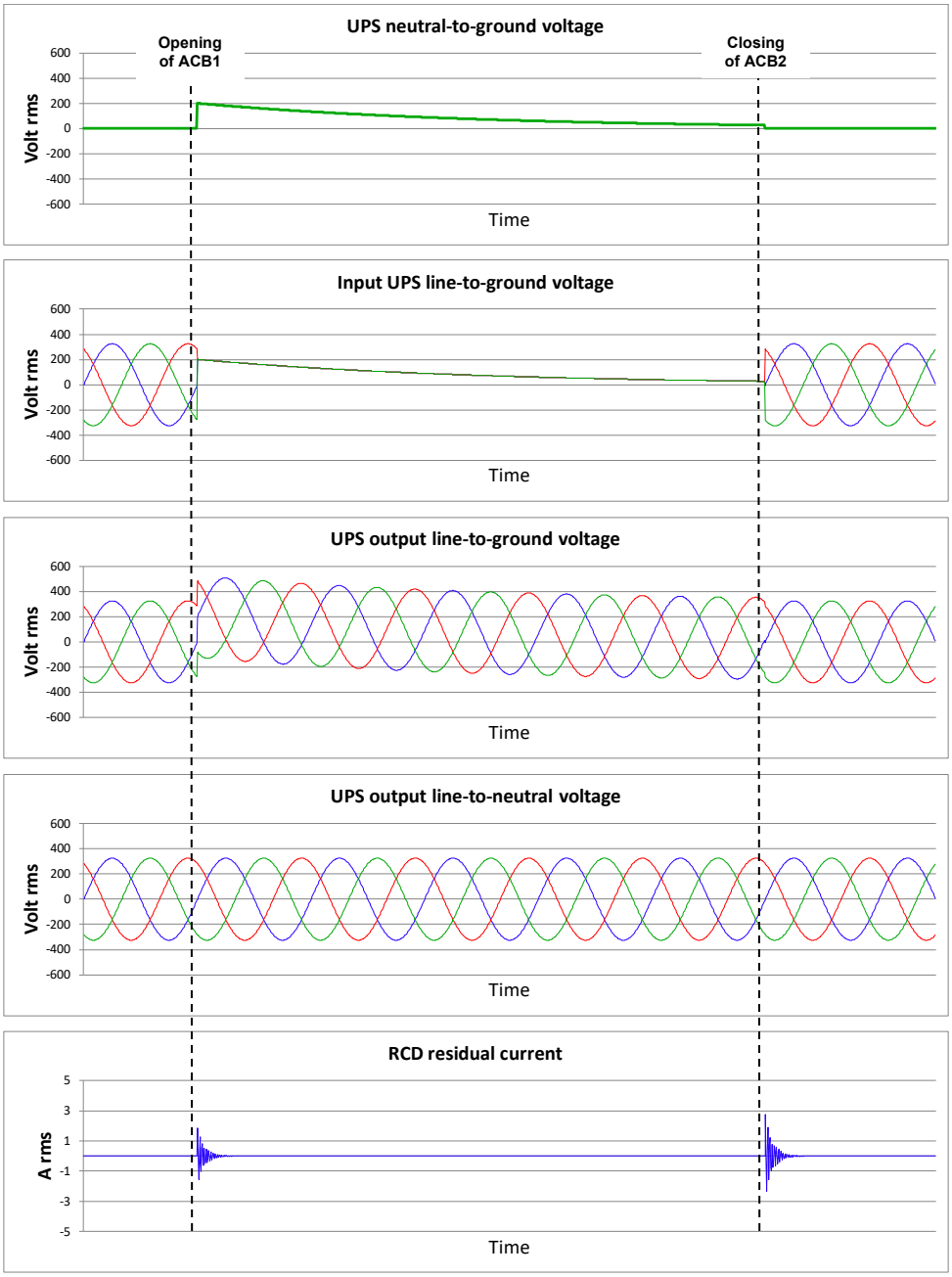


Figure 5

Common mode voltage during the opening of 4-pole CBs upstream of the UPS

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The consequences of this are listed below:

- A common mode overvoltage (line-to-ground) ranging from a few cycles to seconds and in magnitude from a few volts to a few hundred volts, could trip the server's PSU overvoltage protection, leading to downtime. The risk of tripping the overvoltage protection is much higher when the event happens several times per year (e.g., from monthly generator tests using the Automatic Transfer Switch (ATS) with an open transition).
- Common mode current in the residual current devices (RCD) at around a few amps with a frequency of around a few kHz lasting for less than half a cycle. If an AC-type 30 mA RCD is loaded close to its upper limit (10 mA maximum leakage current), some false tripping (i.e., unintended tripping) could happen as a result of this transient common mode current while other RCDs such as type A, SI, and B are not sensitive to this type of transient.

Ground fault during UPS ungrounded operation

If a ground fault happens while the UPS operates ungrounded in battery mode (e.g., during an ATS changeover or after a CB upstream of the UPS trips):

- the line-to-ground voltage on one phase may reach the line-to-line voltage magnitude and may cause server PSUs to trip and go into overvoltage protection; Note, however, the occurrence of such an event is very rare.
- if a double ground fault occurs, the circuit breaker that trips may be not sized to break the current as the voltage across the CB pole can reach the line-to-line voltage. However, the occurrence of a such event is extremely rare.

Electromagnetic disturbances with TNC-S grounding system

To avoid the loss of the neutral wire's reference to ground, some installations are designed with a TNC-S earthing system. The main drawback of the TNC system is that the neutral currents are flowing in the protective earthed neutral (PEN) conductor, the equipment frames, and the communication cable shields. This can cause the loss of equipment equipotentiality and some radiated electromagnetic fields. Both disturbances can lead to information technology (IT) equipment malfunction.

Loss of PE equipotentiality

Figure 6 shows a TNC-S system where some currents are flowing in the PEN conductor and the communication cable shield between the two communication equipment. These currents cause the loss of equipotentiality between the two devices and can cause malfunctions for low immunity data connections (such as Modbus, RS485, RS232, for more details see White Paper 87, "*Grounding and the Use of the Signal Reference Grid in Data Centers*".

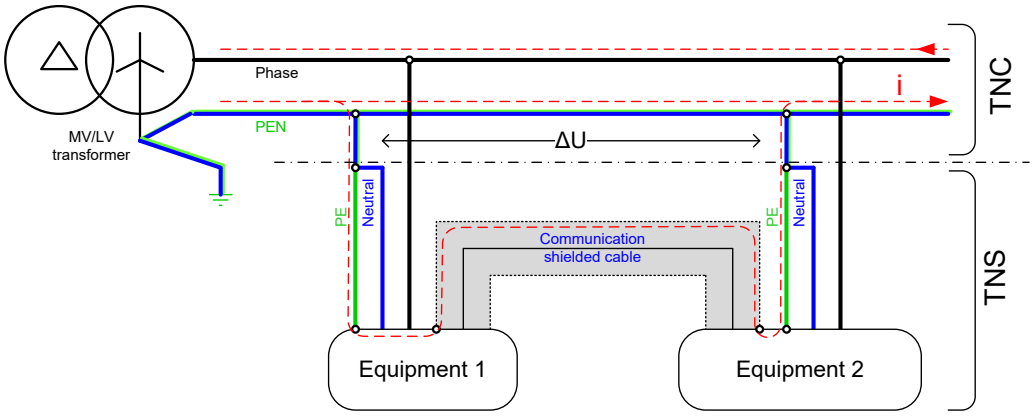


Figure 6

Circulating current in the cable shields in the TNC-S earthing system

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As an example, Figure 7 shows how due to the equipment 1 inrush currents (with harmonic contents, 100 A with 5 µs ramp time), the voltage along the 25 meter PEN conductor can reach 25 µH x 100 A / 5 µs = 500 V. For sensitive equipment (load n°1), this voltage between the PE conductor and the earth can lead to equipment malfunction.

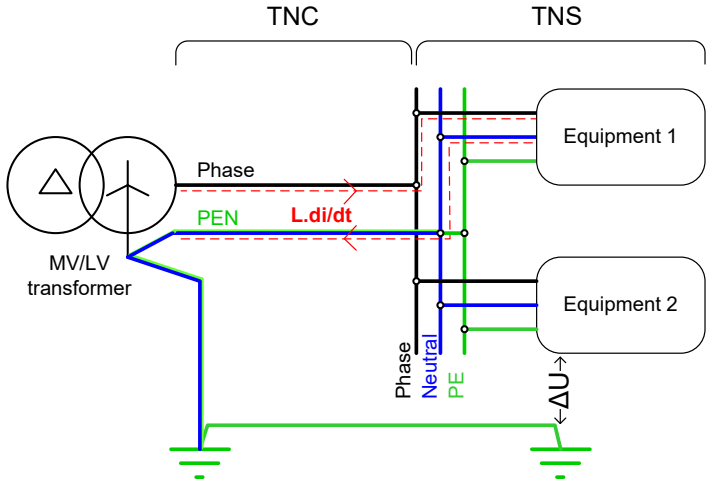


Figure 7

Voltage across the PEN in TNC-S earthing system

PEN loops

In a TNC-S system as show in Figure 8, the PEN conductors can be in parallel. In this configuration, when a circuit is disconnected, as the PEN cannot be disconnected, a part of the neutral current from the other side will continue to flow in this PEN causing a radiated magnetic field that could disturb communication systems nearby the PEN.

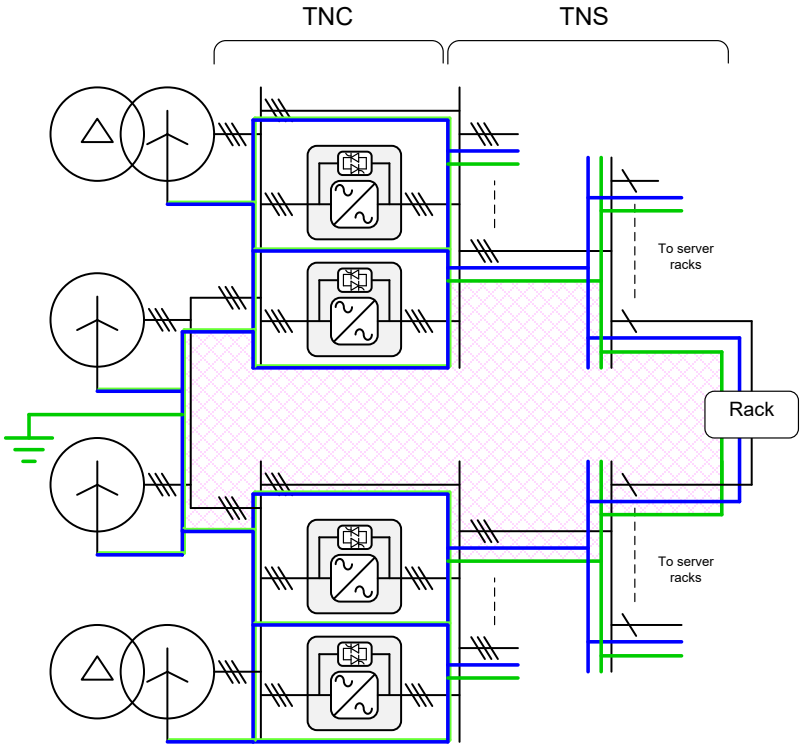


Figure 8

PEN loop in TNC-S earthing system

Moreover, the PEN loop can be the source of induced impulse power transients in the event of nearby lightning strikes.

Recommendations for TNC-S system:

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- To minimize the loss of equipotentiality, the PEN conductor length should be as short as possible (10 meters is a good value to avoid any problems).
- To avoid or minimize the effect of PEN loops, the PEN loop surface should be as small as possible.
- To limit the current circulating in the PE and the equipment frames, the PEN shall be connected to the earth at a single point; this recommendation is applicable at the switchgear level and also at the power system level.
- In the TNS part of the installation, it is recommended to use 4 pole-based equipment (i.e., circuit breakers, contactors, static switches).
- LV installation standards require the use of a TNS grounding system in a building containing a significant amount of information technology equipment (see IEC60364-4-44 444.4.3.1, NFC15100 444.3.12, NF EN 50174-2 and EN 50310). The French standards NFC15100 and NF EN 50174-2 mention that a PEN conductor can be tolerated between the entrance and the first point of connection. After this point of connection, the neutral and PE conductors shall be separated.

Load separation between IT loads and mechanical loads

The main loads in a data center (as shown in Figure 9) are the IT equipment such as servers, switches, routers, and storage and the mechanical loads such as chillers, air handling units, and water pumps. Considering a typical data center LV power system supplying non-linear loads such as pumps, compressors, fans equipped with variable speed drives, and also the server power supplies, the power system design needs to ensure limited disturbances avoiding any troubles for the different loads.

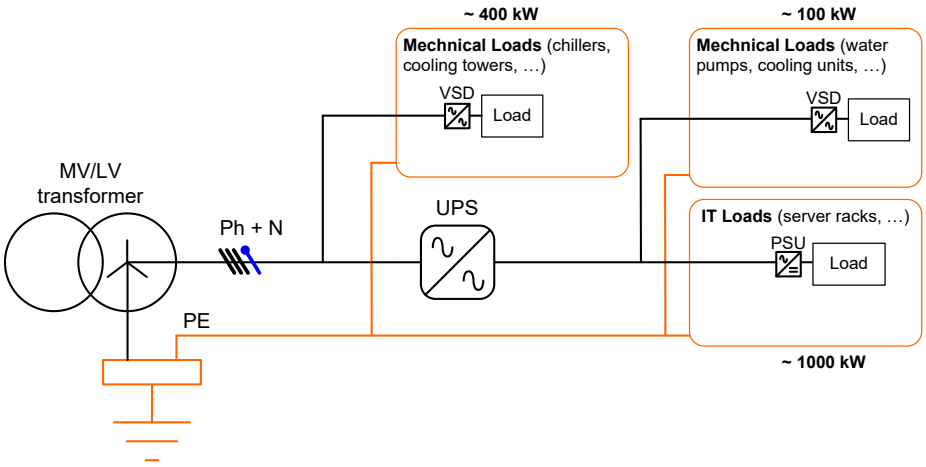


Figure 9

Example of a typical data center LV power system supplying mechanical and IT loads

Even in a TNS configuration, the non-linear loads can still induce some disturbances such as the phase current harmonics that induce voltage harmonics along the cable impedance and the MV/LV transformer impedance (as shown in Figure 10). Sensitive equipment such as IT equipment or mechanical loads can malfunction and/or even be damaged if the voltage harmonics are too high.

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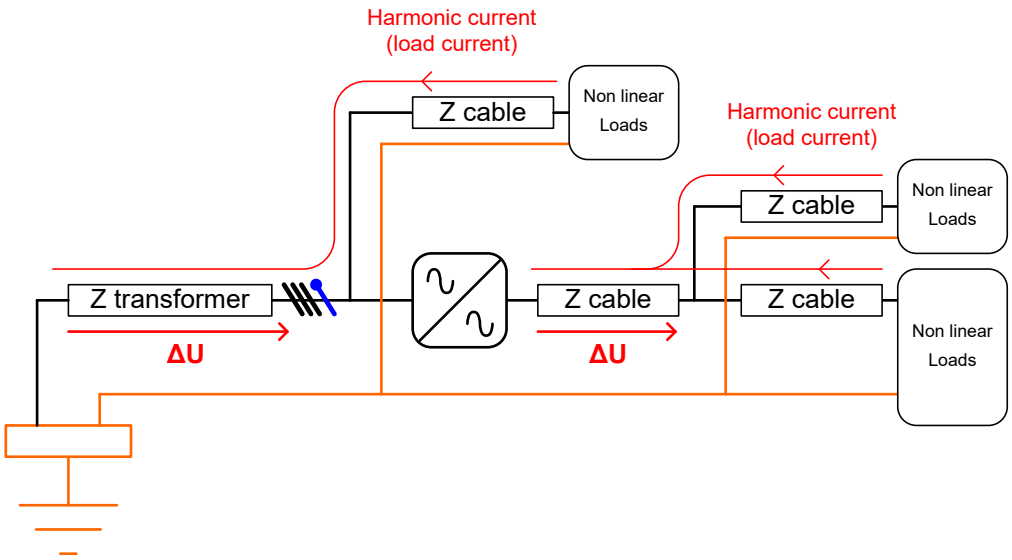


Figure 10

Harmonics current flowing in a typical data center LV power system

Due to equipment cable stray capacitance and the equipment's EMC filters, some low frequency and high frequency common mode currents can circulate in the PE conductors and the communication cables shields as shown in **Figure 11**.

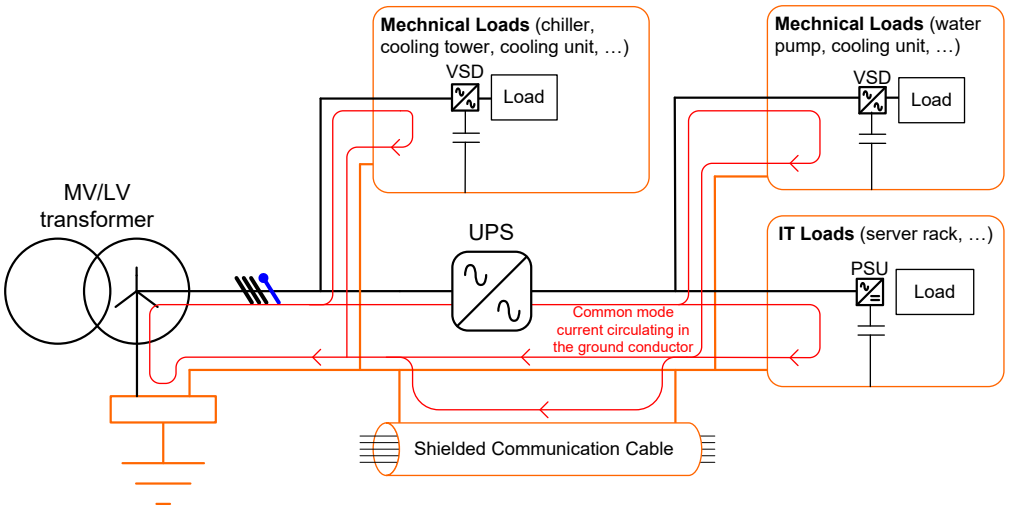


Figure 11

Common mode currents in a typical data center LV power system

Common mode currents cannot be predicted easily. The common mode circuit is made of the stray capacitances and inductances of the wires and all equipment frames and mechanical parts. Mitigation techniques are needed in case EMC requirements are not met when equipment is not robust enough against the present EMI levels. Decoupling devices such as isolation transformers can be used for conducted disturbances; galvanic isolation of the power supply for sensitive equipment is recommended to avoid circulating current on the ground and to limit phase-to-ground common mode voltage transients.

Recommendations for load separation

To minimize the voltage harmonics and EMC disturbances on the IT loads due to current leakage in the PE conductors, the mechanical loads can be isolated from the servers (for more details, see the **Appendix**). However, some end users have experienced no issues while the server racks and the chillers are supplied by the same MV/LV transformer without any galvanic isolation between the loads. **To conclude, when it is possible, it is better to supply mechanical loads and IT racks with different MV/LV transformers and different LV standby generators.**

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Assessment of different distribution alternatives

Several alternatives have been proposed to avoid the loss of neutral reference to ground. Below, for each alternative, we sum up in tables the technical assessment for each solution according to the following attributes:

- end user constraints around design, installation, and the acceptability according to installation standards
- technical risks including potential issues due to transient overvoltages and EMI
- electrical losses representing the additional losses from transformers
- capital expenses (CAPEX)

NOTE: the power architecture of each solution is illustrated using a typical UPS system design where there are two UPS units in parallel with individual static bypass and a common manual bypass. The table provides a simple star rating for each attribute.

Solution 1: TNS with 4-pole CB (i.e., the 'base case')

This solution, considered as the base case for comparison, is the typical TNS distribution with 4 pole circuit breakers.

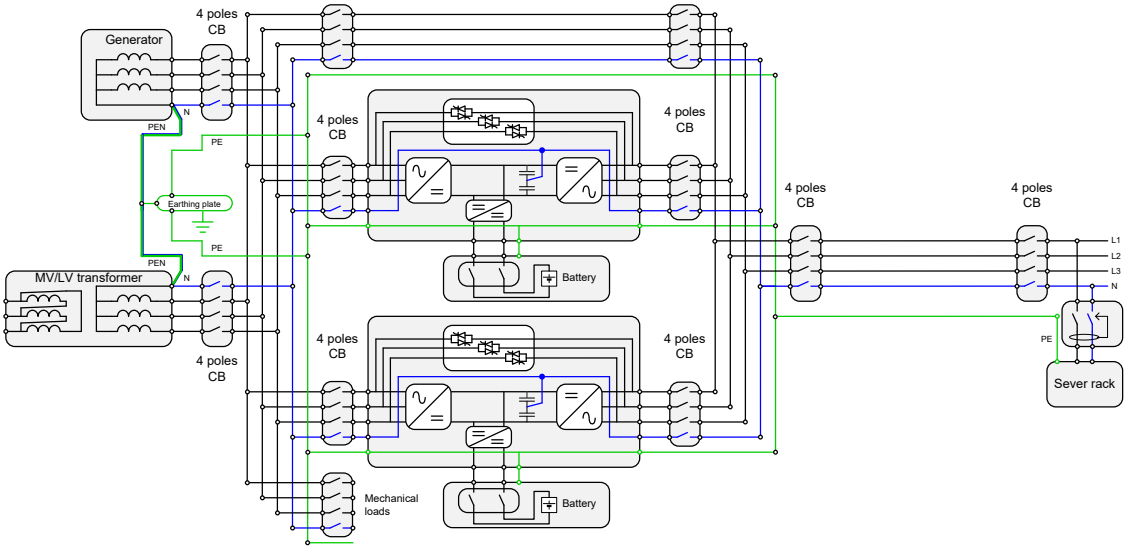


Table 1

Technical summary of Solution 1: TNS with 4-pole CB

End user constraints	Technical risk	Electrical losses	CAPEX
• According to UTEC15402, the UPS downstream network shall be designed for both TNS and ungrounded system. Most of the time, the electrical distribution equipment is certified for ungrounded operation. However, for colocation business, checking the compatibility of server PSUs can be difficult.	• If the server PSUs are not compatible with ungrounded system operations, there is risk of server PSU damage during LV ATS open transition (1 to 10 times per year) or if a fault occurs close to the UPS units (< 1 time per 100 years)	• No additional losses • (base case)	• No additional cost • (base case)
★★★½	★☆☆☆	★★★½	★★★½

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Solution 2: TNS with PDU transformer

When using a LV/LV isolation transformer called “PDU transformer” downstream the UPS system, the server neutral reference to ground is made at the PDU transformer. The distribution from the main LV switchgear to the PDU transformer has no neutral wire. In this case, there is no issue with the loss of UPS reference to the ground, as the server reference to the ground is connected at the LV/LV transformer secondary star point.

The PSU transformer will increase the electrical losses, by adding few percent of the transformer’s rated apparent power, depending on the real load factor. To minimize these additional losses, the isolation transformer can be designed with low losses, but this will add more CAPEX.

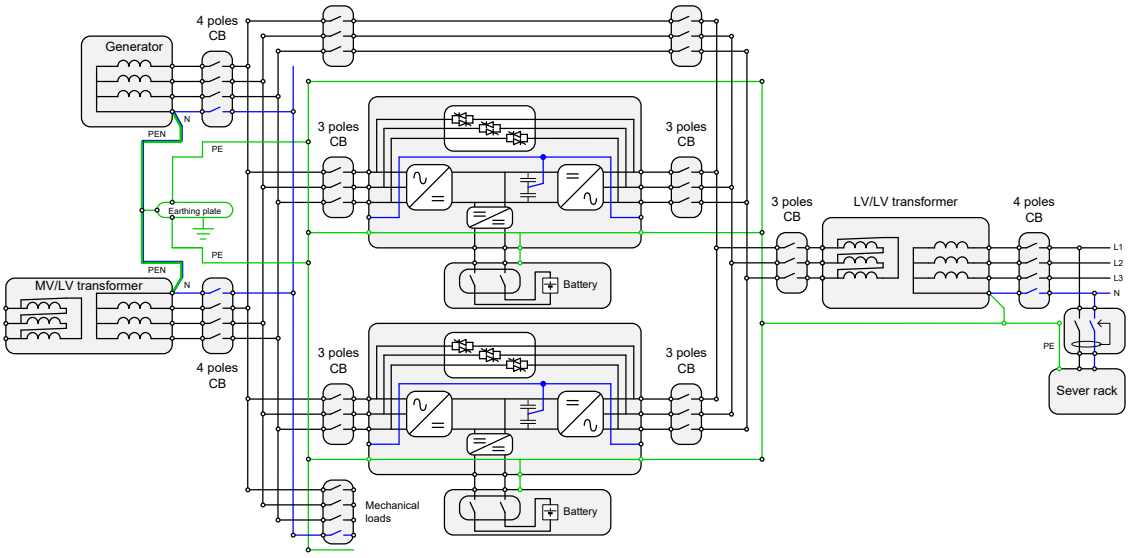


Table 2

Technical summary of Solution 2: TNS with PDU transformer

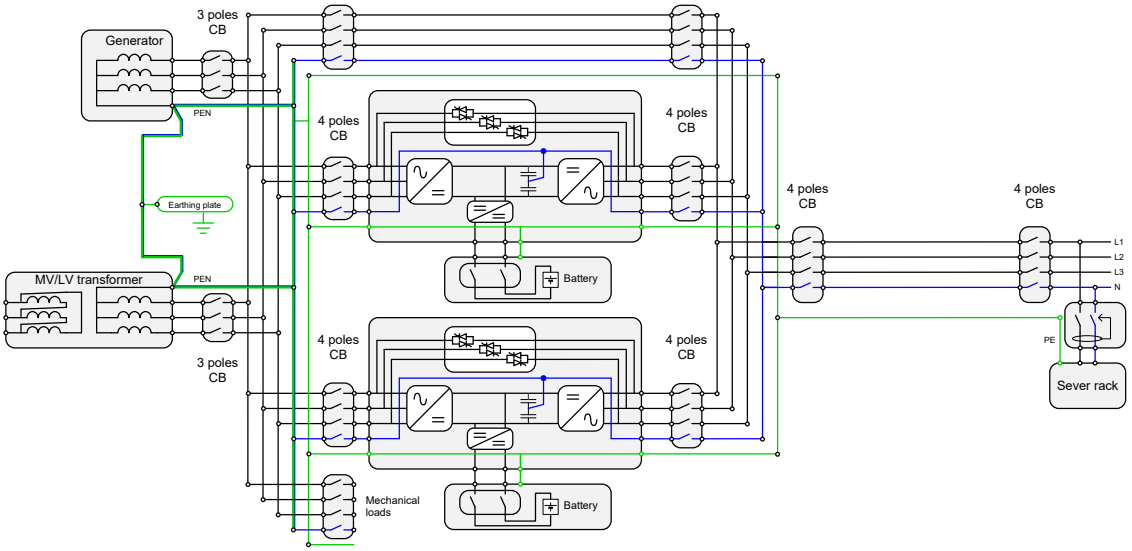
End user constraints	Technical risk	Electrical losses	CAPEX
• No constraints	• Benefits from server rack galvanic isolation in term of EMC • No risk of server PSU damage as the neutral reference to the ground is connected at the PDU isolation transformer	• Standard isolation transformer losses • +3% losses in the PDU transformers at full load • +1.1% losses in the PDU transformers at 50% load	• Additional costs: • PDU transformer cost • More footprint in the IT room • Cost savings: • Only 3-pole CBs and no neutral conductors for UPS connection and distribution to PDUs
★★★★	★★★★	★☆☆☆	★★★☆

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Solution 3: TNC-S from the sources to the main LV switchgear

The idea of Solution 3 is to use TNC earthing system from the sources to the main LV switchgear. The UPS neutral reference to the ground is solidly connected to the PE at the main LV switchgear input busbar. The UPS and the downstream distribution are wired in TNS.

When the ATS is switching, the server neutral reference to the ground will not be lost. However, for the TNC part of the system, the PEN should be as short as possible to limit the risk of loss of ground equipotentiality and EMC issues. This can be done easily between the MV/LV transformer and the main LV switchgear but between the generator and the main LV switchgear, this can more difficult depending on the generator installation constraints.



End user constraints	Technical risk	Electrical losses	CAPEX
• The length between the main LV switchgear and the MV/LV transformer or the LV generator should be as shorter as possible (10m is a good value to avoid problems) • Avoid or minimize PEN loops • Not compliant with IEC60364-4-44 444.4.3.1 that does not allow TNC in the data center	• If the server PSUs are not compatible with ungrounded system operations, there is a risk of server PSU damage if a fault occurs close to the UPS units (< 1 time per 100 years)	• No additional losses • (base case)	• Cost savings: • Only 3-pole CBs and PEN instead neutral an PE conductors from the sources to the main LV switchgear
★★☆☆	★★★☆	★★★☆	★★★★

Table 3

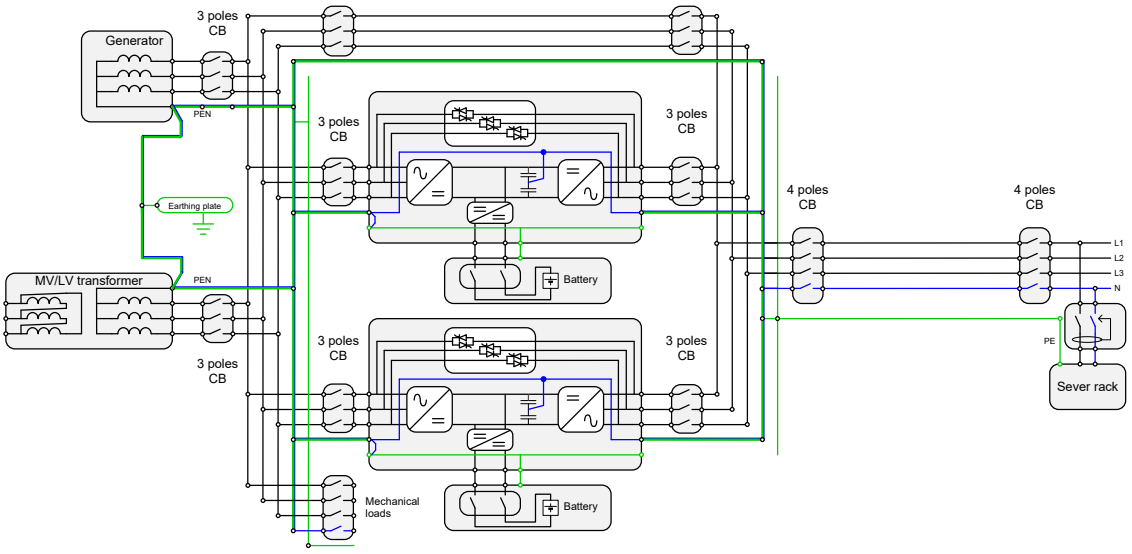
Technical summary of Solution 3: TNC-S from the sources to the main LV switchgear

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Solution 4: TNC-S from the sources to the UPS output switch-board

For solution 4, the TNC earthing system is used from the sources to the UPS output switchgear. The UPS neutral reference to the ground is solidly connected to the PE at the UPS output switchgear. The distribution downstream the UPS output switch-gear is wired in TNS.

As for the previous solution, the server neutral reference to the ground will not be lost during the ATS changeover and also when the UPS input CB is opened. How-ever, the PEN length will be greater than the previous solution as the PEN goes from the sources to the UPS output switchgear. To keep this conductor as short as possi-ble the system composed of the sources, the switchgear and the UPS should as compact as possible. If not possible, a good practice would be to separate the me-chanical loads and the servers with a different MV/LV supply to limit the EMC issues with TNC earthing system.



End user constraints	Technical risk	Electrical losses	CAPEX
• The length between the sources and the UPS output busbar should be as short as possible otherwise it is better to separate IT and mechanical loads on different MV/LV transformers & generators • Avoid or minimize PEN loops (for exam-ple with tie between LV switchgears) • Not compliant with IEC60364-4-44 444.4.3.1 which does not allow TNC in the data center	• No risk of server PSU damage as the neu-tral reference to the ground is solidly con-nected at the UPS in-put (PEN conductor) • The PEN long length and the PEN loops could lead to some EMI	• No additional losses • (base case)	• Cost sav-ings: • Only 3-pole CBs and no neutral conductors from the sources to the UPS
★☆☆☆	★★★★	★★★★	★★★★

Table 4

Technical summary of Solution 4: TNC-S from the sources to the UPS output switchboard

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Solution 5: TNS with 3-pole CB

When allowed by the local rules, the TNS earthing system with 3 pole CB ensures at any moment that the neutral reference to ground is solidly connect to the ground at the source level.

Using 3 pole CB, the server neutral reference to ground will never be interrupted during ATS changeover or UPS input CB opening. However, this solution may be not acceptable by local rules as the TNS with 3 pole CB and parallel circuit has several drawbacks:

- The neutral conductor that will carry the unbalanced currents will induce an electromagnetic field that could lead to EMC issues
- During maintenance, the neutral conductor is a live conductor that is not disconnected and that could reach dangerous voltage levels.

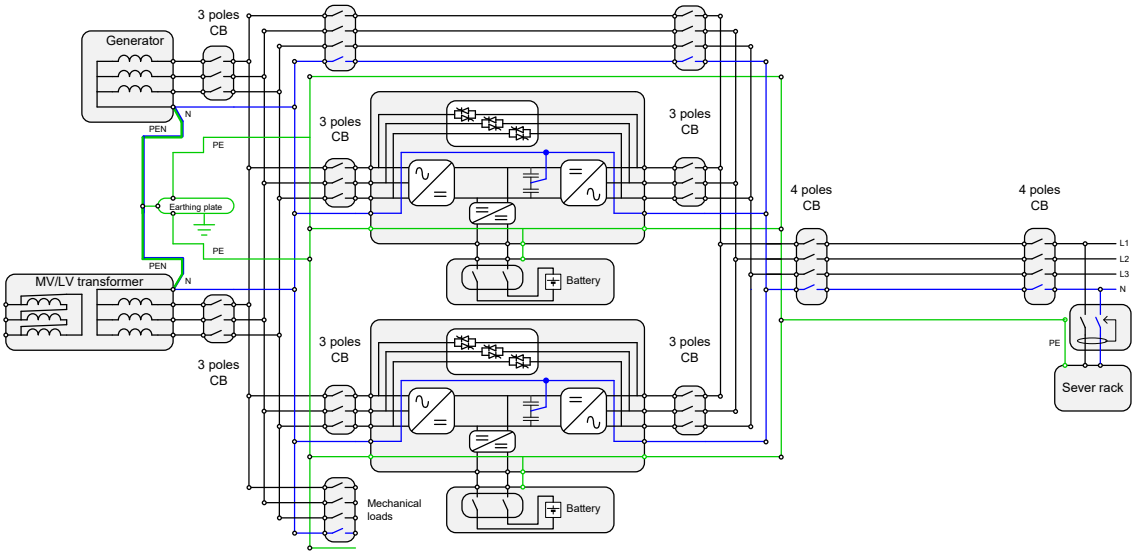


Table 5

Technical summary of Solution 5: TNS with 3-pole CB

End user constraints	Technical risk	Electrical losses	CAPEX
• Depending on the country, TNS 4 wires with 3-pole CB is not allowed by the local electric code • No RCD should be installed on the UPS incomer or generator incomer • Particular attention must be made during the maintenance next to the neutral conductor that is not disconnected	• No risk of server PSU damage as the neutral reference to the ground cannot be disconnected by the sources' CBs or the UPS input CBs • The neutral conductor loop surface could lead to some EMI	• No additional losses • (base case)	• Cost savings: • 3-pole CBs from the sources to the UPS
★☆☆☆	★★★☆	★★★☆	★★★★

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Solution 6: TNS with UPS output neutral earthing

This solution is based on the recommendation of the LV installation standard IEC60364-4-44-444.4.6.1 that recommend in case of multiple sources, that the star point of the sources shall be interconnected and earthed at one single point.

As the UPS can be considered as a source when operating in battery mode, the UPS DC mid-point is connected with the transformer and generator star points to the earthing plate with a PEN conductor. In this case, the UPS output neutral is solidly connected to the earth. Technically, this option works perfectly as the UPS output neutral is solidly connected to the earth and does have any weak points in term of EMC or protection.

However, this is not a use case described clearly by the installation standards and this could be a problem when considering the acceptability of such diagram for different countries and end-users. Another weak point is the complexity to connect an additional PEN cable in the UPS frame as it has not been designed for that.

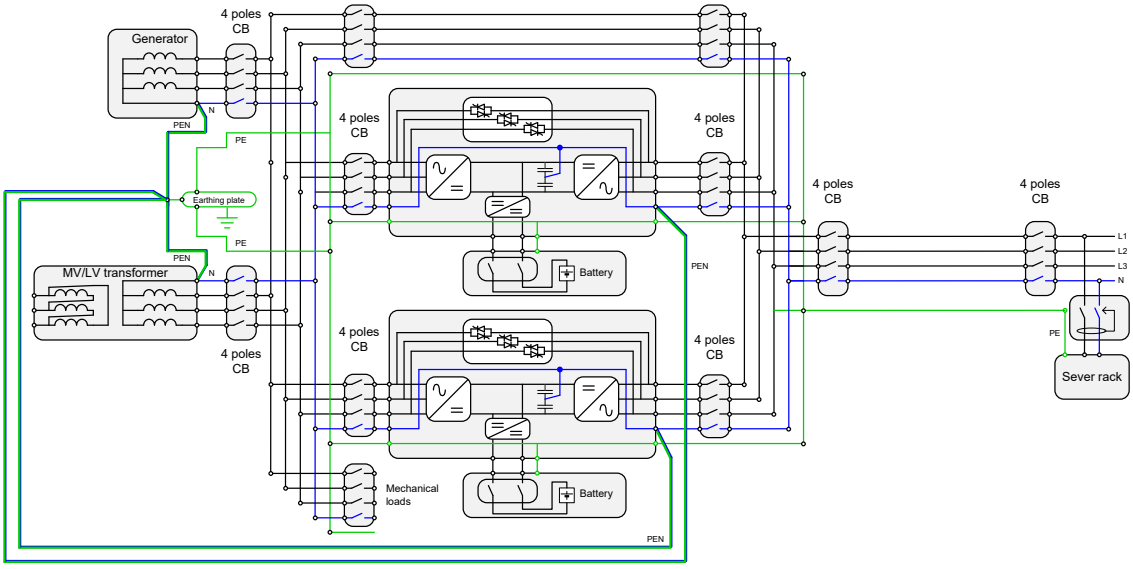


Table 6

Technical summary of Solution 6: TNS with UPS output neutral earthing

End user constraints	Technical risk	Electrical losses	CAPEX
• May not be compliant with local electric code • Not compatible with all UPS ranges (lack of space in the UPS unit to add a PEN conductor) • No RCD should be installed upstream the UPS	• No risk of server PSU damage as the neutral reference to ground is solidly connected at the UPS • bypass transformer	• No additional losses • (base case)	• Added costs: • UPS neutral earthing conductor between UPS units and the source earthing plate
★☆☆☆	★★★★	★★★☆	★★☆☆

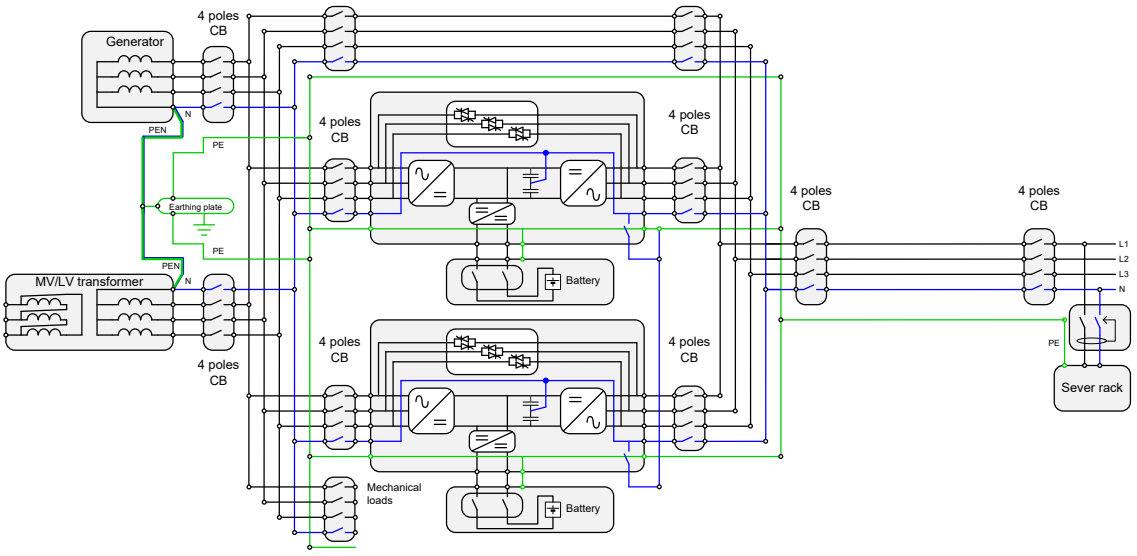
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Solution 7: TNS with UPS neutral earthing contactor

The UPS internal earthing contactor can be used to connect the UPS output neutral to the earth when one of the UPS upstream CBs is opened.

This solution has several drawbacks:

- During, the contactor closing time, the UPS remains ungrounded and the downstream network will still experience an overvoltage.
- The use of a contactor to ground an installation is not a common practice and may be not allowed by local rules. This contactor should be monitored and periodically controlled to ensure that its contacts are not welded.



End user constraints	Technical risk	Electrical losses	CAPEX
• May not be compliant with local electric code • May not compatible with all UPS ranges	• Must check feasibility of connecting UPS neutral conductors together depending on the specific UPS • Possible reliability & availability issues re-lated to installation given possible failures of the automatic UPS earthing devices • If the server PSUs are not compatible with ungrounded system operations, there is a risk of server PSU damage during LV ATS open transition (1 to 10 times/yr) or a ground fault downstream of the UPS and servers (< 1 time per 1000 yrs)	• No additional losses • (base case)	• Added costs: • UPS neutral earthing conductor between UPS units
★★☆☆	★☆☆☆	★★★☆	★★★☆

Table 7

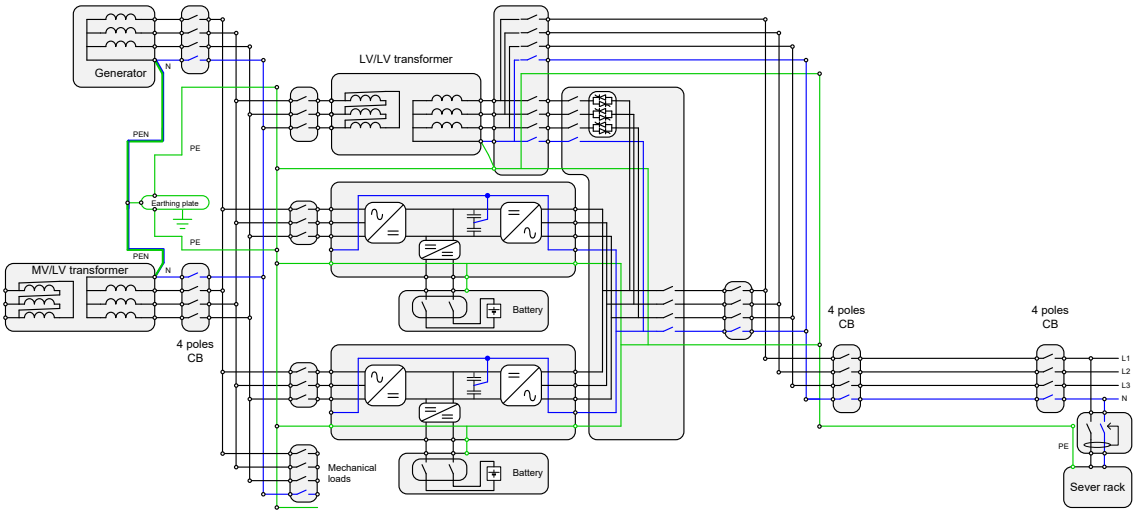
Technical summary of Solution 7: TNS with UPS neutral earthing contactor

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Solution 8: Isolation transformer on bypass (grounded neutral)

The use of isolation transformer with transformer-less UPS is required when using different earthing systems. Here the idea to use an isolation transformer on the by-pass and to connect the secondary star point to the earth.

The UPS output neutral solidly connect to the ground. However, this solution has a serious issue as in normal mode, the circulating current between the UPS and its static bypass neutral will flow in the PE conductor.



End user constraints	Technical risk	Electrical losses	CAPEX
• The circulating current that flows continuously in the PE conductors is not compliant with most of grid code • Must use external main static switch	• No risk of server PSU damage as the neutral reference to ground is solidly connected at the UPS bypass transformer • A circulation current between the UPS main input and bypass input will flow in the PE conductor of the isolation transformer feeder	• Standard isolation transformer losses of +0.33 % in the isolation transformers (UPS is in double conversion mode) • +1.98 % losses in the isolation transformers (UPS in eco mode at 100% load) • +0.7 % losses in the isolation transformers (UPS in eco mode at 50% load)	• Additional costs: • UPS bypass transformer cost (only standby transformer design) • Larger footprint in the UPS room • Cost savings: • Only 3-pole CBs on the UPS bypass feeder
★☆☆☆	★★☆☆	★★☆☆	★★☆☆

Table 8

Technical summary of Solution 8: Isolation transformer on bypass (grounded neutral)

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Solution 9: ATS with neutral overlapping

To solve the issue of loss of neutral reference to the ground during the ATS switching operation, an idea is to use an ATS with a neutral overlapping function. The ATS is able to perform an open transition (break before make) on the phases conductors and to perform a close transition (make before break) on the neutral conductors.

The advantage of this solution is that the installation can be basically wired in TNS with 4 pole CB at each level with a very low risk of loosing the UPS neutral reference to the ground. However, the weak point is the additional cost related to the ATS as this ATS need a dedicated switching device in addition to the main LV CBs.

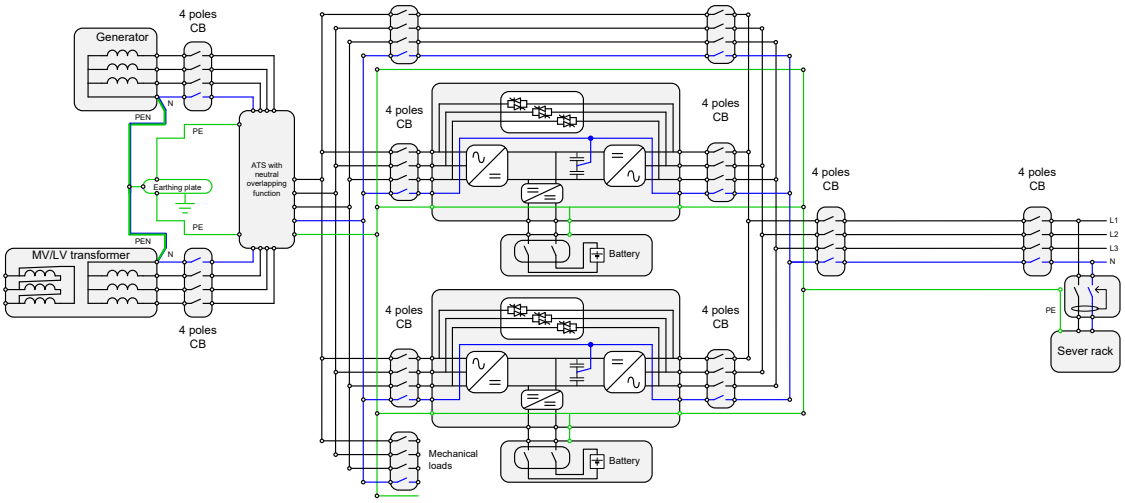


Table 9

Technical summary of Solution 9: ATS with neutral overlapping

End user constraints	Technical risk	Electrical losses	CAPEX
• No constraints	• If single main UPS, there is a risk of server PSU damage when UPS bypass upstream CB opens (< 1 time per 100 yrs) • If dual mains UPS, no risk of server PSU damage	• No additional losses • (base case)	• Additional cost for the ATS with neutral overlapping (compared to an ATS with only 2 CBs in the main LV switchgear)
★★★★	★★★½	★★★½	★★½☆

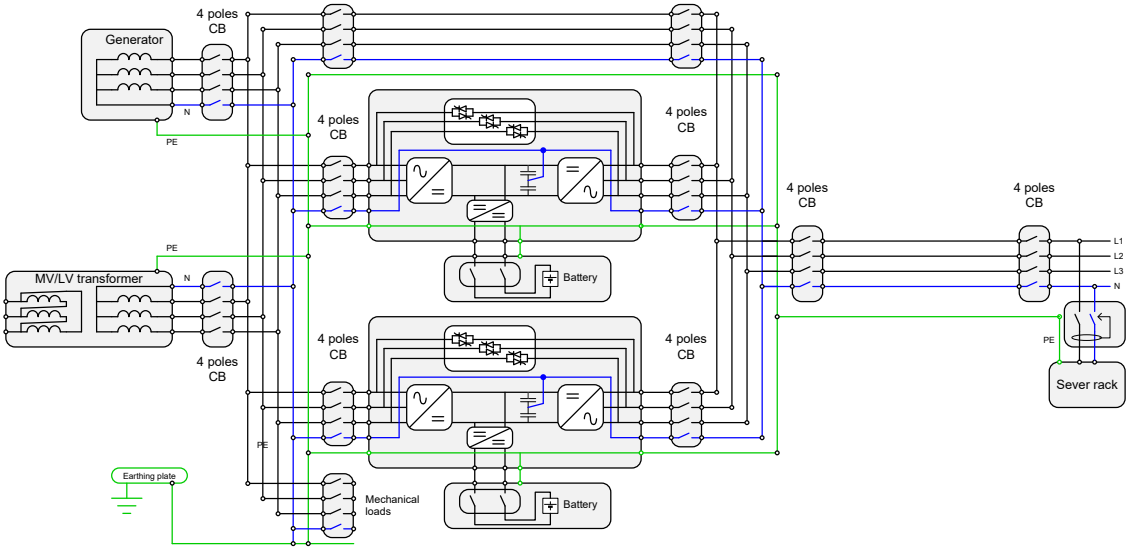
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Solution 10: TNS with earthing at the main LV switchgear

Another arrangement is to keep the TNS earthing system with 4 pole CB and ground the sources at the switchgear level. With this solution, there is no risk to loose the neutral reference to the ground during the ATS changeover.

Several drawbacks are the following:

- This solution is not described in IEC 60364-44- **444.4.6.1**;
- When the main LV CB is opened, the source will operate ungrounded and may require a disconnectable isolation monitoring device to be able to detect any ground fault before connecting the source to the main LV switchgear.



End user constraints	Technical risk	Electrical losses	CAPEX
• The solution is not described in IEC 60364-44- 444.4.6.1 • No possibility to supply several switchgears with one LV generator plant • No possibility to use tie between switchgears A & B • A disconnectable IMD or a 59N protection can be installed to detect any earth fault on the transformer side or the generator when the main LV CB is opened	• If single main UPS, there is a risk of server PSU damage when UPS bypass upstream CB opens (< 1 time per 100 yrs) • If dual mains UPS, no risk of server PSU damage	• No additional losses • (base case)	• No additional CAPEX (base case), if using single mains UPS
★☆☆☆	★★★☆	★★★☆	★★★☆

Table 10

Technical summary of Solution 10: TNS with earthing at the main LV switchgear

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Summary of comparisons

When considering a typical LV distribution system for a data center using TNS and 4-pole CBs from the source down to the loads, the opening of a circuit breaker upstream of the UPS will cause the loss of reference to ground for the UPS. This kind of event can cause various risks such as tripping server power supplies (i.e., overvoltage protection trip) and the tripping of sensitive rack RCDs, except if type A or SI RCDs are used. This risk is significant when this event might have several opportunities a year to occur such as during the ATS changeover when the generators are tested. According to this statement, it is recommended to avoid the loss of neutral reference to the ground during the ATS changeover.

Several solutions have been assessed and are summarized here in Table 11.

Table 11

Scoring summary of all of the distribution solutions considered in this study

Solution alternatives	End user constraints	Technical risk	Electrical losses	CAPEX
Solution 1: "TNS with 4-pole CB"	★★★☆	★☆☆☆	★★★☆	★★★☆
Solution 2: "TNS with PDU transformer"	★★★★	★★★★	★☆☆☆	★★★☆
Solution 3: "TNC-S from the sources to the main LV switchgear"	★★☆☆	★★★☆	★★★☆	★★★★
Solution 4: "TNC-S from the sources to the UPS output switchboard"	★☆☆☆	★★★☆	★★★☆	★★★★
Solution 5: "TNS with 3-pole CB"	★☆☆☆	★★★☆	★★★☆	★★★★
Solution 6: "TNS with UPS output neutral earthing"	★☆☆☆	★★★★	★★★☆	★★☆☆
Solution 7: "TNS with UPS neutral earthing contactor"	★★☆☆	★☆☆☆	★★★☆	★★★☆
Solution 8: "Isolation transformer on bypass (with grounded neutral)"	★☆☆☆	★★☆☆	★★☆☆	★☆☆☆
Solution 9: "ATS with neutral overlapping"	★★★★	★★★☆	★★★☆	★☆☆☆
Solution 10: "TNS with earthing at the main LV switchgear"	★☆☆☆	★★★☆	★★★☆	★★★☆

Conclusion

The analysis shows that there is no one perfect solution. The main goal of this paper was to provide important technical insights to enable the electrical designer to select the best options according to their local installation characteristics and end user targets.

The two best solutions for minimizing risks (i.e., PSU failures and EMC-related issues) are Solution 2, “TNS with PDU transformer” and Solution 9, “ATS with neutral overlapping”.

The best compromise on cost versus risk are shown below based on specific conditions:

- If there is no LV automatic changeover upstream of the UPS, the risk of losing the neutral reference to ground is very low. So, Solution 1, “TNS with 4-pole CB”, is suitable in this case.
- If there is a generator that is not shared with other switchgears and there’s no tie between main LV switchgears, Solution 10, “TNS with earthing at the main LV switchgear”, is an easy solution to implement.
- If there is a generator shared with several LV switchgears and/or a tie between two main LV switchgears, Solution 3, “TNC-S from the sources to the main LV switchgear”, and Solution 4, “TNC-S from the sources to the UPS output switchboard” are cost effective, however, particular attention shall be paid to avoid EMC issues by minimizing the length of the PEN and the PEN loop surface. And, if possible, by suppling the server racks and the mechanical loads by separate MV/LV transformer will further help avoid EMC issues.
- Note that Solution 6, which consists of grounding the UPS neutral with a PEN, can provide a very good compromise in terms of CAPEX and risk mitigation if it is acceptable by the local standards and if suitable with that particular UPS’s connections.

About the authors

Malik Megdiche received his Master of Science degree and his PhD in Electrical Engineering from the National Polytechnic Institute of Grenoble (INPG) in 2001 and 2004. He is presently a power system engineer and reliability expert in Schneider Electric company. His main fields of interest are medium and low voltage power system design, protection, simulation and reliability assessment.

Avelino De Oliveira received his Master of Science degree in Electrical Engineering from the National Polytechnic Institute of Grenoble (INPG) in 1992. He joined Merlin Gerin (Now Schneider Electric) in 1993. He started by the development of UPS 10kVA to 120kVA & STS during 15years and after he started to do many studies (Selectivity, stability, load flow,…) to be a Senior principal Architect Power System in charge of the design optimization for different segment (Hotel, Healthcare, Food & bev, Transportation…).

Eric Brun received his bachelor’s degree in Electronics from CNAM of Grenoble, France, his master’s degree in applied sciences from CESI of Grenoble/Lyon, France, and his MBA from IAE/ESA from University of Grenoble France. He is presently Power Conversion Distinguished Architect at Schneider-Electric. In this role he researches the best available technologies and architectures related to power quality and energy efficiency, to improve the development of future products and data center power systems. He also has leading positions in several international standard committees linked to UPS and power conversion systems.

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Appendix

Neutral distribution alternatives

Depending on the countries and the habits, several grounding system and neutral distribution principles are used.

Figure A1

US habit:
3 phase distribution (TNS without neutral) from the sources to the PDU cabinets
Neutral distribution from the PDU isolating transformer to the racks
The UPS DC midpoint can be solidly earthed, or an earthing transformer can be installed down-stream the UPS

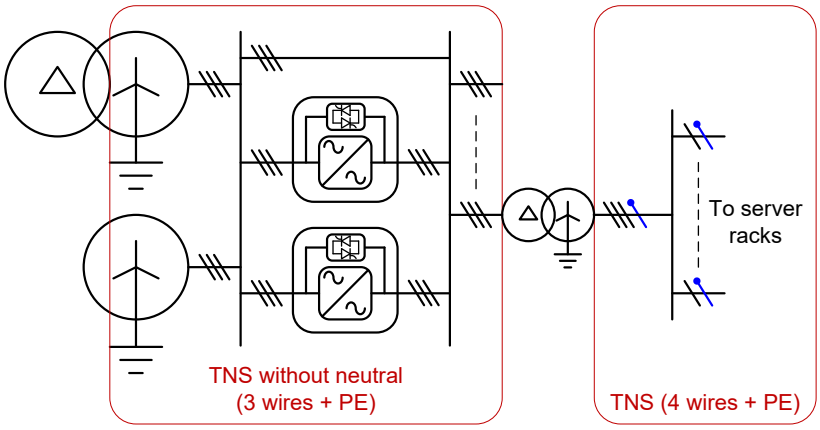


Figure A2

European habit (for last 2 decades)
3 phase distribution (TNS without neutral) from the main LV switchgear to the UPS and isolation transformer
3 phases distribution (TNS 4wires) from the UPS output to the rack distribution panels (RPP)
The UPS DC midpoint is connected to the bypass isolation transformer neutral

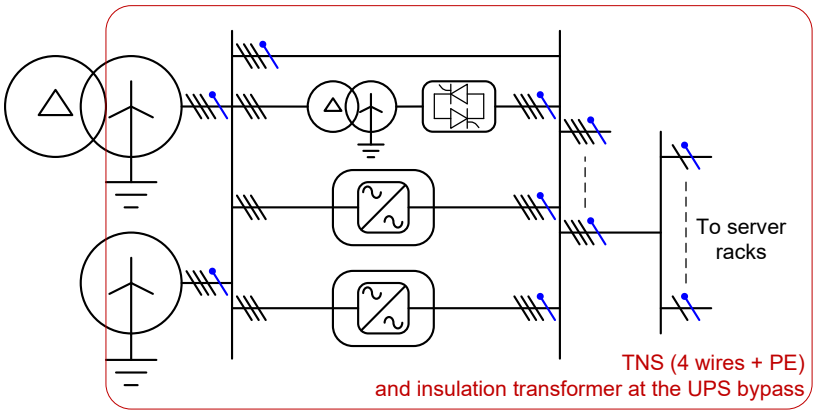
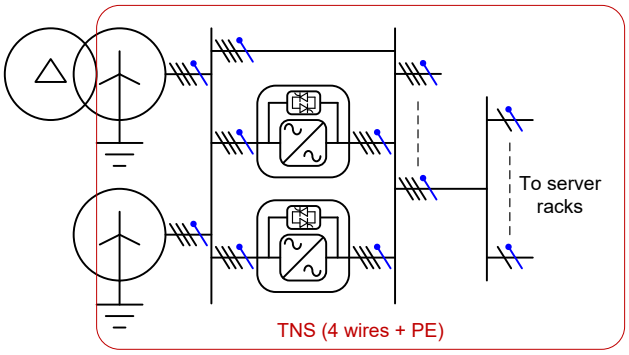


Figure A3

European habit

3 phase distribution (TNS 4wires) from the source to the rack distribution panels (RPP)

The UPS DC midpoint is connected to the bypass neutral



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Figure A4

European habit

3 phase distribution (TNC 3 wire) from the sources to the main LV switchgear to UPS output switchboard

TNS 4 wire from the main LV switchgear to the PDU cabinets

The UPS DC midpoint is connected to the bypass neutral

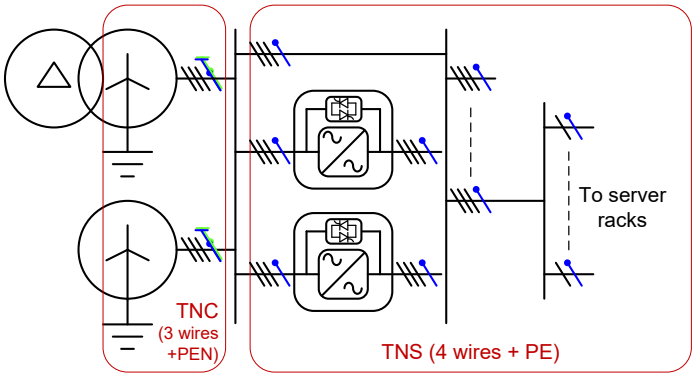


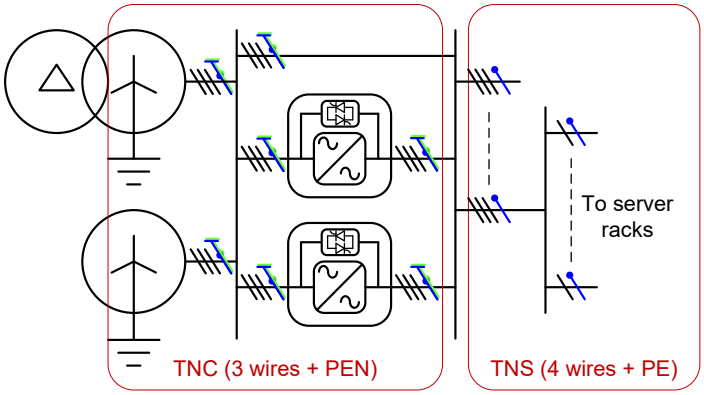
Figure A5

European habit

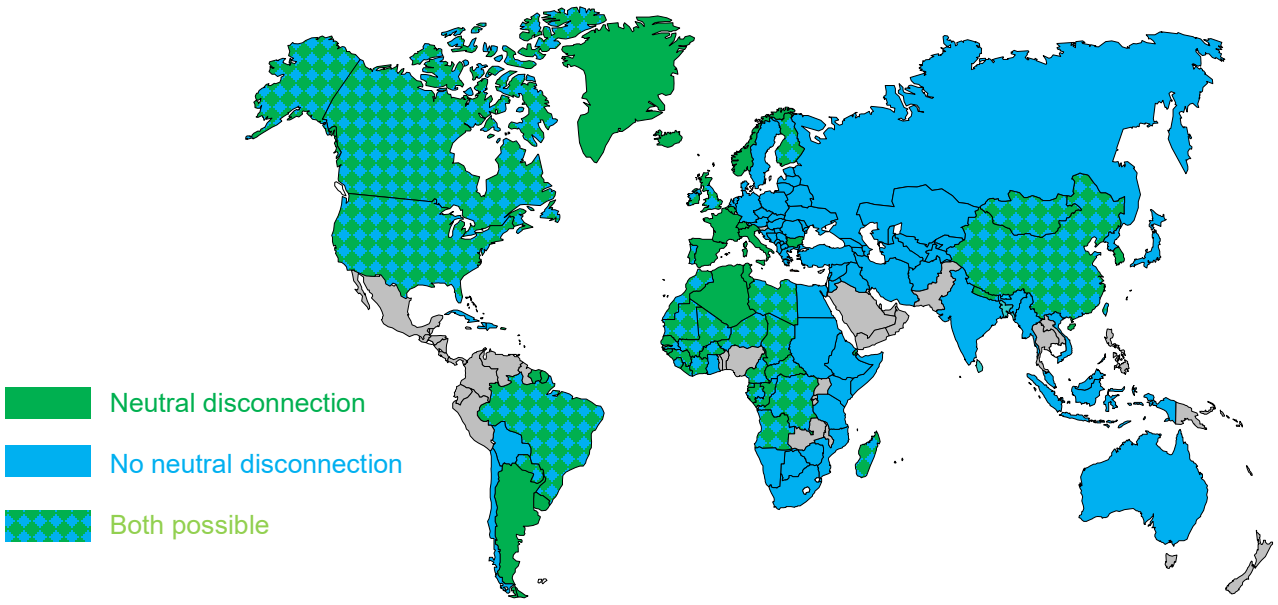
3 phase distribution (TNC 3 wire) from the sources to UPS output switchboard

TNS 4wire from the UPS output switchboard to the PDU cabinets

The UPS DC midpoint is connected to the PEN conductor



Disconnection of the neutral conductor around the world



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