Data Center Energy White Paper 06 — Common Grounding Systems for Data Centers

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Preface

As you know, in China, TN-S is usually used in data centers as the grounding system. What is the meaning of TN-S? What are differences between it and other grounding systems such as TT and IT? What are their advantages and disadvantages? This document introduces these grounding systems.

1. Introduction to Grounding Methods of Low-voltage Power Supply and Distribution Systems

Low-voltage AC power supply and distribution systems are classified into TT, TN, and IT based on grounding methods. TN is most commonly used. TN systems are further classified into TN-C, TN-S, and TN-C-S based on whether their protective neutral wire is separated from the working neutral wire.

For categories of low-voltage AC power supply and distribution systems, see IEC 60364-1. Grounding methods of power supply and distribution systems are represented by Latin letters. For example, the meaning of TN-S is as follows.

Table 1 Meaning of each letter in the grounding system name

The first letter shows the relationship between the power supply and the ground.	T (French Terre): The power supply has one point directly grounded.
	I (French Isoland): All electrified parts of the power supply are not grounded or the power supply has one point grounded with impedance.
The second letter shows the relationship between conductive exposed parts of the electric installation and the ground.	T (French Terre): Conductive exposed parts of the electric installation are directly grounded. This grounding point is independent from the grounding point of the power supply in terms of electrical connection.
	N (French Neutre): Conductive exposed parts of the electric installation have direct electrical connections with the grounding point of the power supply.

The letter after the dash "–" shows the combination situation of the neutral conductor and the protective conductor.	S (French Separateur): The neutral conductor and the protective conductor are separated.
	C (French Combinaison): The neutral conductor and the protective conductor are combined into one.

Based on preceding definitions, we can deduce meanings of names of common grounding systems.

Table 2 Meanings of grounding system names

Grounding System	Lower-level Classification	Power Supply	Device	Device Grounding and Power Supply Grounding	Whether Neutral Wire and Ground Wire Are Separated?
TT	\	Grounded	Grounded	Not directly connected	—
IT	\	Not grounded or grounded with impedance	Grounded	Not directly connected	—
TN	TN-C	Grounded	Grounded	Have direct connections	Separated
	TN-S	Grounded	Grounded	Have direct connections	Combined into one
	TN-C-S	Grounded	Grounded	Have direct connections	Combined into one in the power supply and separated in devices

2. Comparison of Grounding Methods of Low-voltage Power Supply and Distribution Systems

As for grounding methods, what needs to be considered first is the safety of grounding systems.

Safety means that personnel and devices are not harmed in power supply and distribution. Reliability refers to the capability of uninterruptible power supply. This is a pair of contradiction in the power supply system. When personnel safety and device safety are

threatened, the power supply needs to be cut off, which will influence power supply for electric devices. In the following, five common AC power supply and distribution systems and their grounding methods are introduced. Comparative analysis is conducted from the aspects of safety and reliability.

What needs attention is that the same type of rather than multiple types of power supply systems should be used in an area, to ensure operations of electric devices in a safe and reliable manner.

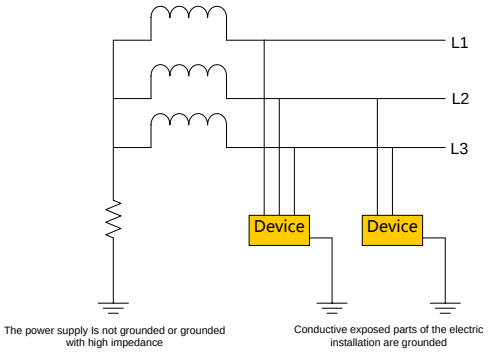
2.1 IT System and Grounding Method

The IT system is a three-phase, three-wire power supply and grounding system. The neutral point of the transformer of the system is not grounded or grounded with high impedance. The system has no N wire. PE wires of electric devices are grounded separately.

The IT system has high reliability and safety when the power supply distance is not very long. The system is usually used in the places where power failure is not allowed or where the continuous power supply is a strict requirement, for example, in places of steel-making with electric power, operating rooms of large hospitals, underground mines, and tunnel command centers and for specific devices serving as the important communication hub. However, the system has high requirements for voltage withstanding of electric devices. In underground mines, power supply conditions are poor. Cables easily get damp. When the IT system is used, even if the power supply neutral point is not grounded, the ground leakage current of a single phase is still low and the balance of power supply voltages is not broken when electric leakage happens on devices. Therefore, the system is safer than other systems whose power supply neutral point is grounded.

However, when the power supply distance is very long, the distributed capacitance to ground of power supply wires cannot be ignored. When the load has a short circuit or the device shell is electrified due to electric leakage, the leakage current flows through the ground, forming a circuit. The protective device may not react to such a situation. This is dangerous. Only when the power supply distance is not very long, can safety be ensured. The system is rarely used in construction sites.

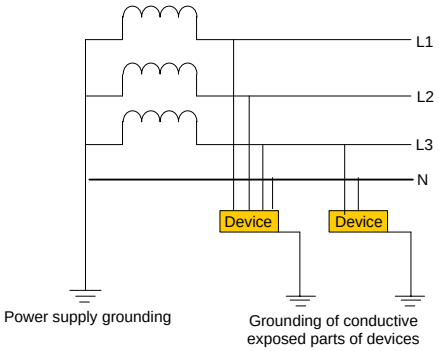
Figure 1 IT system grounding



2.2 TT System and Grounding Method

TT is a protective system that has metal shells of electric devices be directly grounded. It is called the protective grounding system. Its characteristic is that its N wire has no electrical connections with the PE wire. That is, the grounding of the neutral point and grounding of the PE wire are separated. Therefore, shells of electric devices have no direct relationships with the grounding of the power supply. That is, conductive exposed parts of devices have no relationships with grounding points of the system. The system and devices are grounded through their own grounding devices separately.

Figure 2 TT system grounding



The TT system is usually used when the power for devices is supplied by public power grids and is commonly used in the suburban area for civil use.

When the TT system normally runs, no matter whether loads of three phases are balanced or not, the PE wire is not electrified when the N wire is electrified. Therefore, all groundings of loads in the system are called protective groundings. Characteristics of the system are as follows:

(1) When metal shells of electric devices are electrified (phase wires touch shells or

electric leakage happens due to damage of device insulation), the risk that personnel get an electric shock is reduced thanks to grounding protection. However, low-voltage circuit breaker (automatic switched) may not trip out. As a result, the voltage to ground of shells of electrified devices is higher than the safe voltage, which is dangerous.

(2) When the leakage current is low, disconnection may not be realized even there is a fuse. Therefore, the leakage protector needs to be installed for protection. Due to this, the TT system is hard to be promoted.

(3) Grounding devices of the TT system use many steels, which are hard to be recycled. Many working hours are spent and many materials are used.

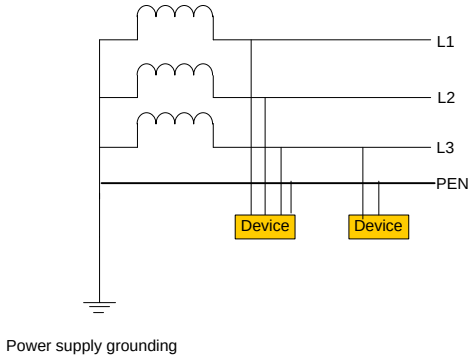
2.3 TN System and Grounding Method

TN is a protective system that connects metal shells of electric devices to the working neutral wire. It is called the connection-to-neutral protective system. Its power system has one point directly grounded. Conductive exposed parts of the electric installation connect to the point through the protective conductor. TN systems are further classified into TN-C, TN-S, and TN-C-S.

2.3.1 TN-C System and Grounding Method

The power supply neutral point of the TN-C system is directly grounded. The neutral wire N leads out protective wire PE or protective neutral wire PEN. It is a three-phase, four-wire system.

Figure 3 TN-C system grounding



The TN-C system is usually called the three-phase, four-wire power supply system. Its neutral wire N and protective ground wire PE combine into one. That is, its working neutral wire also serves as the protective wire and is known as the PEN wire. The system is not applicable to data centers. Main reasons are as follows:

(1) When the system is a single-phase loop, the voltage to ground of metal shells of devices reaches 220 V, a fault voltage, when the PEN wire is disconnected. It is very dangerous as personnel may get electrocuted if they touch shells. If the RCD is installed, the PEN wire passes through the RCD. When the above-mentioned situation happens, the magnetic field generated by the ground-fault current is offset in the RCD. As a result, the RCD does not react to the situation. Therefore, the RCD cannot be installed in the TN-C system to prevent electric shocks as it becomes useless in the system.

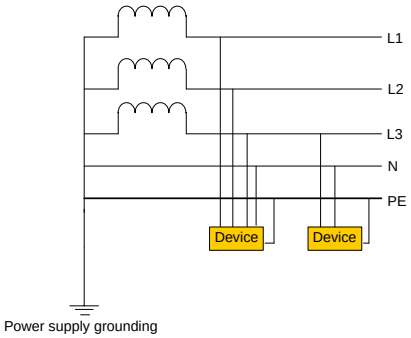
(2) As the PEN wire includes the PE wire, the PEN wire cannot be disconnected by the switch. Therefore, the four-pole switch cannot be installed in the TN-C system. As a result, in electrical repair, repair personnel's safety cannot be ensured.

(3) Metal shells of devices have the electric potential to ground, which may interfere with electronic devices and may also cause exploration. Therefore, in places where exploration easily happens, the TN-C system is not allowed to be used and the PEN wire must not be used.

2.3.2 TN-S System and Grounding Method

The TN-S system has five wires, which are three phase wires U, V, and W, one N wire, and one PE wire. Its power system has only one point grounded. Conductive exposed parts of electric devices, such as shells and racks, connect to the PE wire.

Figure 4 TN-S system grounding



The TN-S system is highly sensitive with grounding faults. Wiring is simple and economical. In general, safety requirements are met only if proper switched protective devices are installed and the conducting wire cross-sectional area is large enough. At present, the system is used in many places. It can be used in places where loads of three phases are relatively balanced and the single-phase load capacity is small. The system can be a preferred choice for data centers. It has the following characteristics:

(1) In the whole TN-S system, the PE wire and N wire are not combined into one. Unless mistakes are made in installation, except very low leakage currents to ground, the PE wire has no currents flow through it and no electric potential. Only fault currents flow through it when grounding faults occur. Therefore, conductive exposed parts of the electric installation nearly have no electric potential to ground. The system is safe.

(2) When phase wires touch shells, it is just like the situation that phase wires have a short circuit to ground. As impedance of the PE wire is very small, the instant short-circuit current is very high. The front-end over-current protector (circuit breaker) switches off. Personnel will not be injured. Therefore, in the TN-S system, the leakage protector is not needed.

(3) When the N wire is disconnected, though the neutral point is electrified due to imbalance of loads on three phases, there is no risk of electric shocks as shells do not have electric potential differences to ground, as the neutral point has no electrical connections with shells.

(4) In principle, the PE wire in the system must not be disconnected. If the PE wire is disconnected, it is just like the situation that shells are not grounded. As a result, the risk of electric shocks emerges. Therefore, repeated grounding needs to be considered for the system to prevent the risk caused by PE wire disconnection.

(5) Though the system has high safety, one more PE wire needs to be laid in the loop of the system. Costs are high.

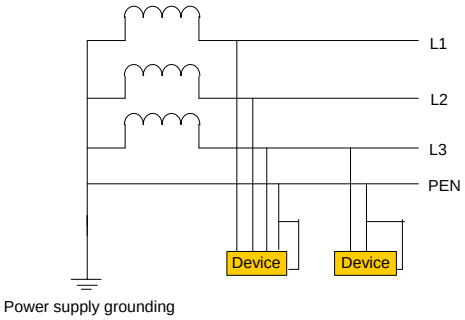
2.3.3 TN-C-S System and Grounding Method

The TN-C-S system consists of two grounding systems. It has four wires in the first part, which is the TN-C system, and five wires in the second part, which is the TN-S system. The demarcation point is the connection point of the N wire and the PE wire. After

separation, combination is not allowed.

The system is usually used in places where the power in civil buildings is supplied by the regional electrical substation. Before deployment in buildings, it is the TN-C system. After deployment in buildings, it becomes the TN-S system. At present, the system is commonly used in new-built data centers and other facilities.

Figure 5 TN-C-S system grounding



As the TN-C-S system uses the PEN wire, a certain electric potential difference to ground is generated on the PEN wire when currents flow through the N wire. As a result, the whole electric installation has the electric potential difference to ground. However, as the PE wire and N wire are separated in the electric installation, no current flows through the PE wire. Therefore, electric potentials to ground are the same and electric potential differences to ground do not exist in the electric installation. Not like the TN-C system, the risk of electric shocks does not exist.

If the PE wire is disconnected, just as the TN-C system, the whole loop is disconnected as a result, which also leads to the problem that shells are electrified. Therefore, as other TN systems, in the TN-C-S system, the PE wire of device shells should be grounded repeatedly. However, the PEN wire should not be grounded repeatedly. If the N wire is disconnected, the PE wire is not electrified and therefore shells are not electrified. Just like the TN-S system, the risk of electric shocks does not exist.

When phase wires touch shells, it is just like the situation that the L wire has a short circuit to the PE wire. The short-circuit current is high. The upstream circuit breaker switches off for protection. Therefore, just as the TN-S system, the leakage protector is not needed.

All in all, the TN-C-S system both has the safety advantage of the TN-S system and the

cost advantage of the TN-C system and avoids safety problems of the TN-C system.

3. Summary

Based on aforesaid introduction, we can make a summary as follows.

Table 3 Comparison of advantages and disadvantages of several grounding systems

Low-voltage Power Supply and Distribution System		Advantages	Disadvantages
TT		The system has the capability of leakage for overvoltage caused by lightning strikes on low-voltage power grids. The leakage protector operates in a reliable manner.	The leakage protector needs to be installed. Many steels are used and are hard to be recycled. Many working hours are spent and many materials are used.
IT		When the power supply distance is not very long, the power supply reliability and electrical safety are high.	The power supply distance is not very long.
TN	TN-C	The PE wire and the N wire are combined into one. One conducting wire is saved, which is economical.	Electrical safety is not high. The system easily interferes with electronic devices and may cause exploration.
	TN-S	Power supply reliability and electrical safety are high. The system can be a preferred choice for data centers.	One more PE wire needs to be laid in the loop of the power supply system. Costs are high.
	TN-C-S	When loads of three phases are balanced, the system both has the safety advantage of the TN-S system and the cost advantage of the TN-C system.	When loads of three phases are imbalanced, safety is not high.

At present, all these grounding systems are used. Among them, the TN-S system is most frequently used. Users should select the proper grounding system based on their actual needs to satisfy self-construction requirements.

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