3 & 4 POLE SWITCHING

OVERVIEW

Choosing between 3 or 4-pole switching can have a direct impact on whether an electrical system functions properly, while it also affects the cost and footprint of any mission-critical power protection system.

Indeed, using the incorrect number of poles not only threatens overall system availability, it can also put individuals' safety at risk of a potentially deadly electric shock.

This whitepaper provides an overview of 3 and 4-pole switching in UPS installations, including how to ensure compliance with the various applicable International Electrotechnical Commission (IEC) standards.

THE BASICS OF 3-POLE & 4-POLE SWITCHING

The number of poles in a switching device such as a circuit breaker, isolator, or transfer switch correlates to the number of circuits the device can protect i.e. a 3-pole device can protect three circuits. Each pole represents an individual switch contained in the breaker, which corresponds to a different wire or phase of electricity.

- ***Overview of 3-Pole Devices***
  These are primarily used in three-phase electrical systems typically found in large buildings or industrial applications. Such systems consist of three different phases of AC electrical current, with each phase protected by one of the poles.

  Unlike a 1-pole device, which only interrupts one conductor of an electrical circuit, a 3-pole device can interrupt all three conductors of a three-phase circuit simultaneously, providing comprehensive protection against overloads and short circuits.

- ***Overview of 4-Pole Devices***
  Offers similar functionality to a 3-pole device but includes an additional pole for the neutral conductor.

  While the neutral wire in an electrical system typically doesn't carry any current, it does provide a return path for the current and in certain circumstances can become 'live', posing a significant safety risk. The fourth pole enables the neutral to be disconnected too, which provides an extra level of protection.

While both types are of device are commonplace in three-phase electrical systems, 4-pole devices tend to be used in scenarios where there is a greater potential for a fault on the neutral wire, for example, systems with unbalanced loads (i.e. where the load on one or more phases differs from the others) or harmonic currents.

POLE SWITCHING IN UPS INSTALLATIONS

In most European countries, low voltage electrical installations follow the international standard *IEC 60364-1 (Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions).*

So while there are some country-specific deviations and best practices, the British Standard BS 7671 – informally known throughout the UK electrical community as 'The Regs' – broadly adheres to the principles of IEC 60364-1.

Earth Referenced Electrical Systems

TN electrical systems have one point connected directly to earth, while the exposed conductive parts of the electrical installation are connected to this point using protective earth conductors.

There are three types of TN systems depending on the arrangement of the neutral and protective conductors:

- **TN-S:** the protective earth conductor is separate throughout the system
- **TN-C:** the neutral and protective earth conductors are combined into a single conductor throughout the system
- **TN-C-S:** the neutral and protective functions are combined into a single conductor in a part of the system

When any of these earth referenced systems are used, the neutral should be connected to the earth reference at all times, even when multiple sources are used.

This ensures safe voltage levels as well the correct functionality of protective devices during earth fault conditions i.e. the supply will disconnect automatically.

In electrical systems without a UPS, it is possible to use a 4-pole transfer switch for the building supply, as opening the switch will deenergise downstream distribution and there's no power applied to the load.

However, this isn't recommended under IEC 60364-1. The preferred method, particularly if there are multiple feeds and current paths, is to use a 4-pole device downstream after the main switchgear.

Abnormal System Voltages

Following the principles of IEC 60364-1 takes on greater importance when a UPS forms part of the electrical system.

Take the following example: the upstream neutral disconnects and the connection to the earth reference for the UPS is lost. When the UPS supports the load, the electrical system starts behaving like a floating IT system, where all live conductors are isolated from earth or one point is connected to earth through a high impedance.

In such circumstances, the voltages, phases, and neutral can potentially drift apart from the earth reference, caused either by inductances in the electrical distribution and components or by stray capacitances.

The worst case scenario could see one of the phases close to earth with the others having a line to line voltage towards the protective earth. Such voltages can be harmful for the load as they may not have been initially designed to operate in a floating IT distribution system.

When using upstream 4-pole breakers and transfer switches with a permanently connected UPS, the neutral conductor may have high voltage against protective earth. Where these hazardous voltages in the neutral conductor appear will depend on the location of the switch and where the neutral disconnects.

Whenever a UPS supply connects through 4-pole devices that will interrupt the neutral when opened or the UPS is connected to an IT power distribution system, warning labels must be fitted on all primary power isolators and access points between such isolators and the UPS.

These warning labels are a requirement as stipulated by the international standard *EN 62040-1:2008 Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS* to alert service personnel about the potential of voltage backfeed.

The labels will contain language with wording similar to the following:

"Risk of Voltage Backfeed. Before working on this circuit isolate the UPS then check for hazardous voltage between all terminals, including the protective earth"

Earth Faults & Automatic Disconnection Of Supplies

The use of 4-pole switching devices upstream of a permanently connected UPS should be avoided because of the potential safety risks to both the load and personnel associated with abnormal system voltages.

However, this isn't the only reason. Automatic disconnection of the power supply is one of the primary safety requirements for any low-voltage electrical installation. This eliminates the risk of touch voltages.

Whenever a 4-pole switch upstream of the UPS is open, and the UPS is running in stored energy mode, the connection to earth is lost and the return path for any fault current is broken. So if you experience an earth fault downstream of the UPS, its invertors can't feed fault current to trip the overcurrent protection.

This means that the requirement for supply disconnection cannot be met. Even worse, since one of the phases is connected to protective earth through a fault impedance, it can send hazardous voltages across the system as the other phases and neutral drift apart.

It is therefore essential to follow the earthing principles of IEC 60364-1 to ensure the correct overcurrent protection and avoid the risk of abnormal voltages caused by a floating neutral.

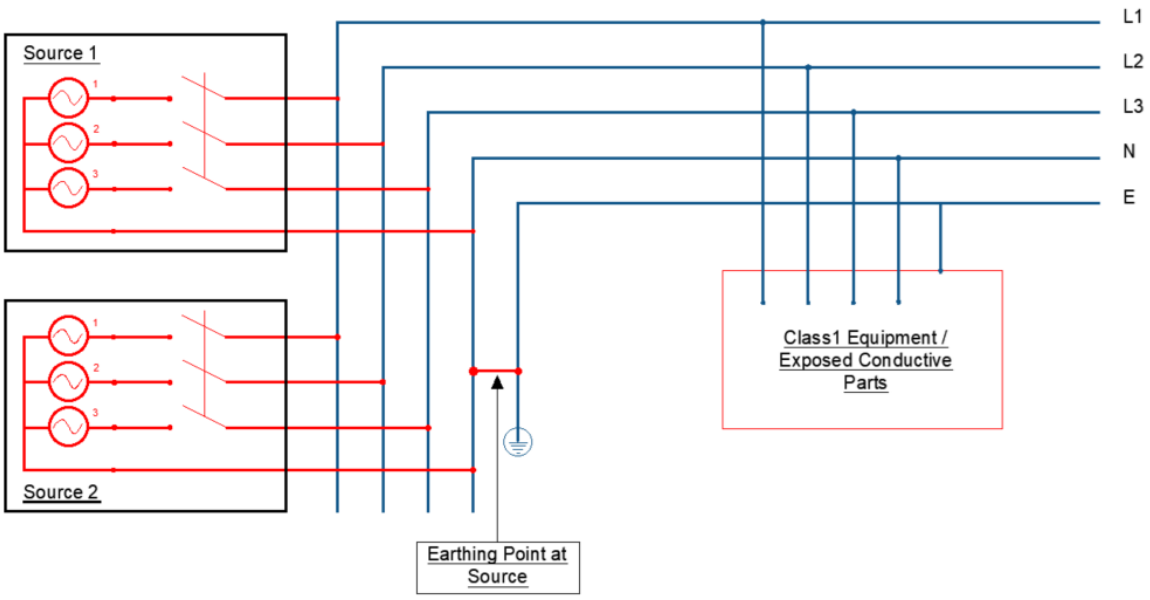

Image 1: Multiple source system following the international standard principles for low-voltage electrical installations.

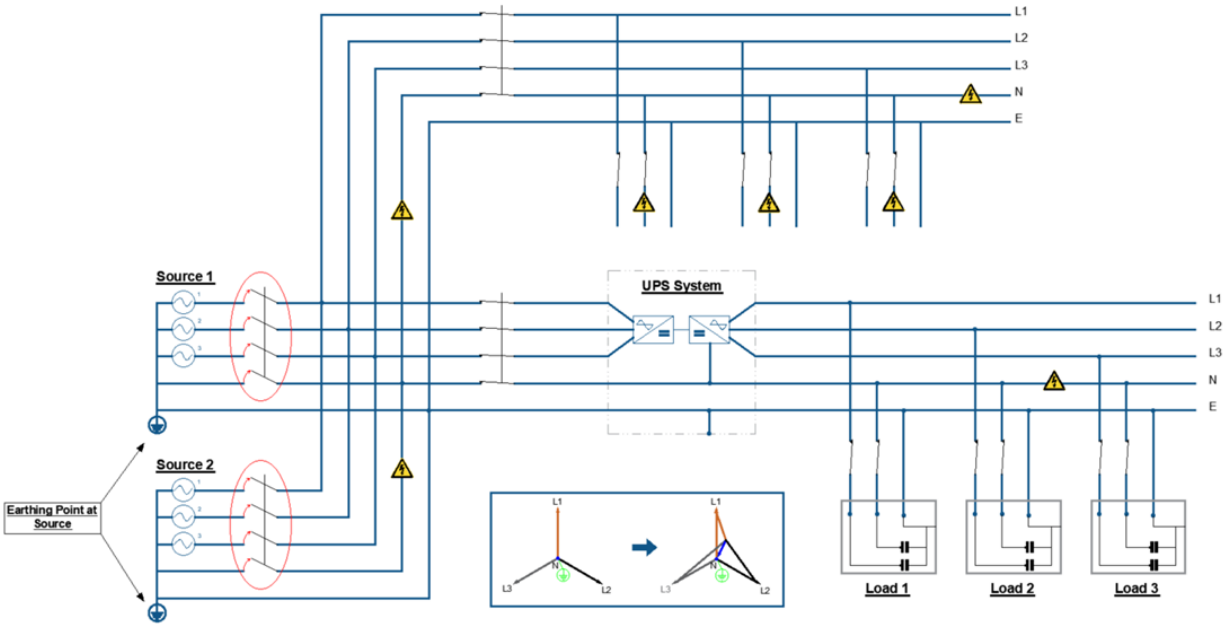

Image 2: When a 4-pole device is opened upstream of a permanently connected UPS, the neutral voltage may drift apart from earth potential and neutral becomes hazardous.

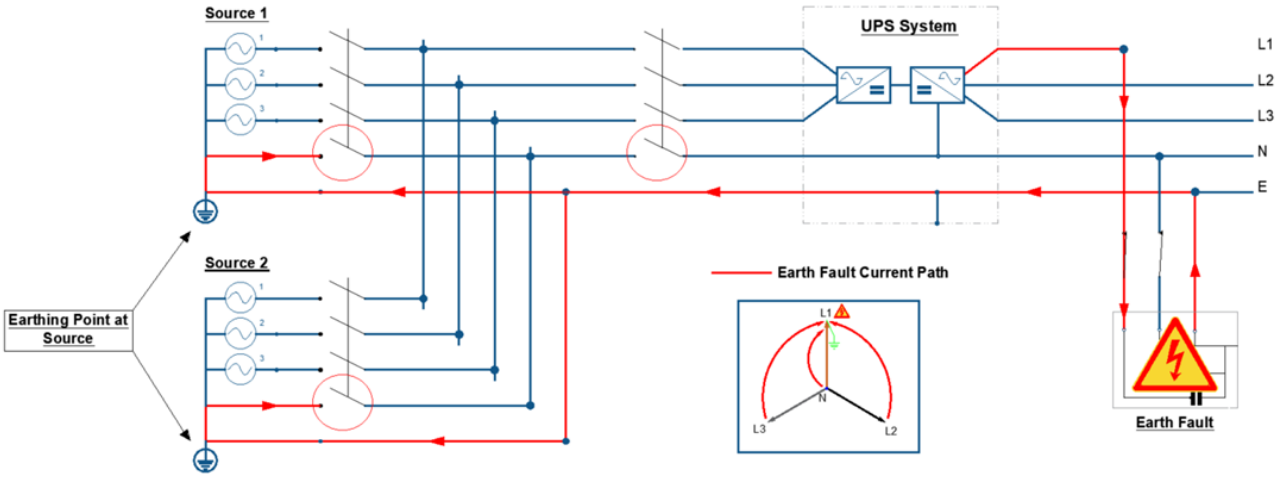

Image 3: The current path for earth fault current in UPS stored energy mode is illustrated by the dotted red line. When 4-pole devices are used upstream of a permanently connected UPS, possible locations for interruption of the fault current path are circled in red. When open, these devices will prevent the operation of any load overcurrent protection and the automatic disconnection of supply.

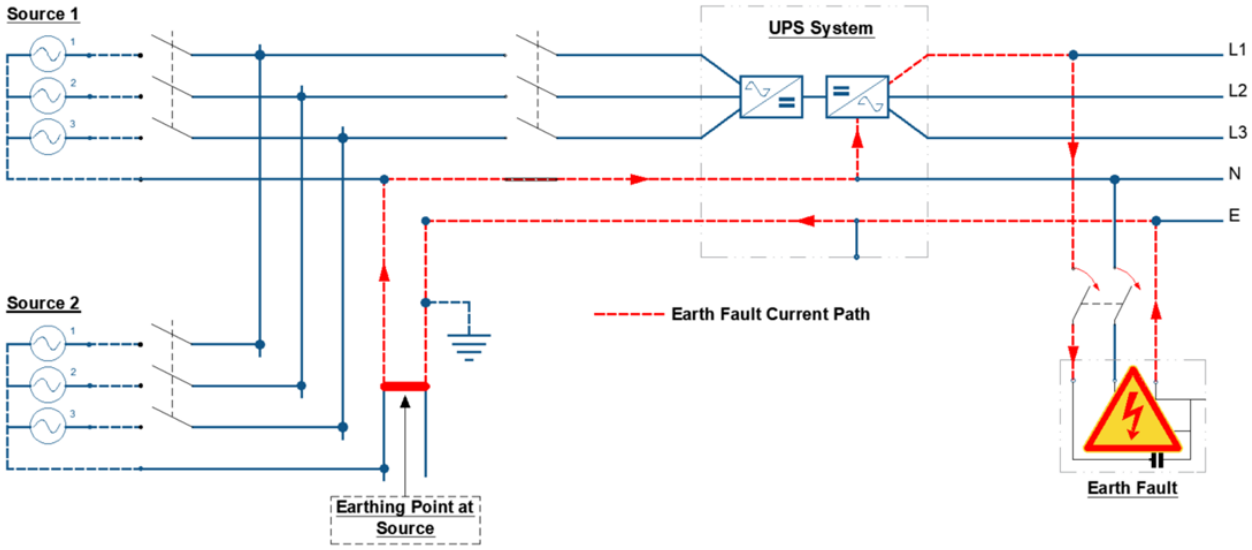

Image 4: The current path for earth fault current in UPS stored energy mode is illustrated by the dotted red line. This illustration follows the international standard principles for low-voltage electrical installations in TN-C-S systems with multiple sources.

Nuisance Tripping

The opening and closing of 4-pole transfer switches can sometimes lead to nuisance tripping of residual current circuit breakers (RCCB).
When both breakers are open during the transfer from one source to another, the electrical system temporarily becomes an IT distribution system.

Voltages can drift from the earth reference because of any inductances or stray capacitances in the system, caused for example by EMI filters.

When the transfer between sources is complete and the breakers close, the neutral connects back to earth reference. This creates a sudden voltage change and a fast, transient current between the phases and neutral towards earth.

Such a scenario can cause EMI filters to produce a transient current into the protective earth conductor, which is sometimes enough to trip residual current protection devices.

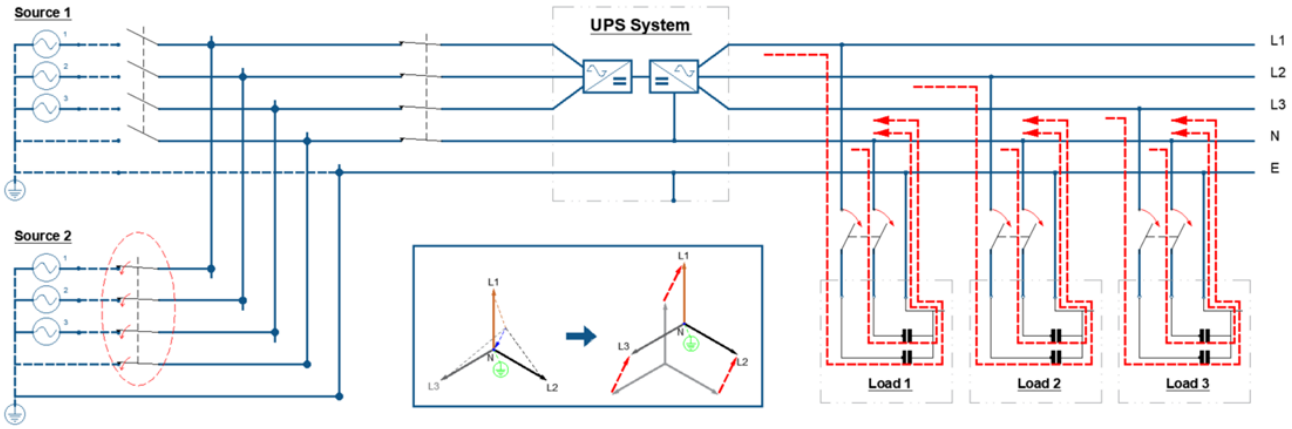

Image 5: Closure of a 4-pole transfer switch could cause current transients, which may lead to nuisance tripping of residual current protection.

3 & 4-Pole Usage

In installations with multiple feeds, 3-pole switches should be used for both transformer and generator incomers, with both sources connected to a mains switchboard with 3 phases and a PEN conductor.

The PE and N will be separated in a TN-S system, with the neutral connected to the earth reference at all times when the load is powered.

Planning for electrical systems with permanently connected or centralised UPS needs to use 3 and/or 4-pole devices appropriately to ensure the correct system performance.

It's important not only to consider normal system operation, but also all fault scenarios and potential component failures.

Particularly complicated power supply arrangements may require a different approach to achieve the correct functionality and safety, for instance using a separate N-PE switching device.

SUMMARY

The decision whether to use 3 or 4-pole switching is crucial for the overall safety and reliability of your electrical system, not to mention your capital costs and regulatory compliance.

An incorrect selection could result in a broad range of knock-on effects, from the nuisance tripping of circuit breakers and overheating of conductors, through to dangerous voltage levels that pose a threat not just to your system availability but the health and safety of service personnel.

It is highly recommended to include discussions about which method to use throughout the process of specifying, designing, installing, and commissioning your UPS system with your preferred manufacturers, consultants, and contractors.

