The Electric Power Supply System

Introduction

In any medium or low voltage three-phase system, there are three single voltages measured between each phase and a common point called the neutral point. The neutral is the common point of three star-connected windings. The neutral may or may not be accessible or distributed. Except in specific cases, the neutral is not distributed at medium voltage. However, the neutral is very often distributed at low voltage. In a medium or low voltage installation, the neutral may or may not be earthed. Therefore there is a need to study about the earthing system.

The earthing system plays a very important role. When an insulation fault occurs or a phase is accidentally earthed, the values taken by the fault currents and over-voltages are closely linked to the type of neutral earthing connection. A directly earthed neutral strongly limits over-voltages but it causes very high fault currents, whereas an unearthed neutral limits fault currents to very low values but the occurrence of over-voltages is high.

In any installation, service continuity in the event of an insulation fault is directly related to the earthing system. An unearthed neutral permits service continuity during an insulation fault. On the other hand, a directly earthed neutral, or low impedance-earthed neutral, causes tripping as soon as the first insulation fault occurs. The extent of the damage to some equipment also depends on the earthing system. In an earthed network, a machine affected by an insulation fault suffers extensive damage due to the large fault currents. However, in an unearthed or high impedance-earthed network, the damage is reduced, but the equipment must have an insulation level compatible with the level of over-voltages.

The choice of earthing system in both low voltage and medium voltage networks depends on the type of installation as well as the type of network. It is also influenced by the type of loads and service continuity required.

Earthing systems at low voltage

Earthing systems are governed by standard IEC 60364-3. There are three types of systems: IT, TT and TN. The first letter defines the neutral point in relation to earth:

T directly earthed neutral
I unearthed or high impedance-earthed neutral

The second letter defines the exposed conductive parts of the electrical installation in relation to earth:

T directly earthed exposed conductive parts
N exposed conductive parts directly connected to the neutral conductor

IT System (Unearthed or Impedance-earthed neutral)

Letter I implies that the neutral is unearthed or connected to earth by a high impedance. Letter T implies that the exposed conductive parts of the loads are interconnected and earthed. A group of loads can be individually earthed if it is situated far away from the other loads.

Advantages:

- System provides the best service continuity during use.
- When an insulation fault occurs, the short-circuit current is very low.

Disadvantages:

- A maintenance personnel is required to monitor the system during use.

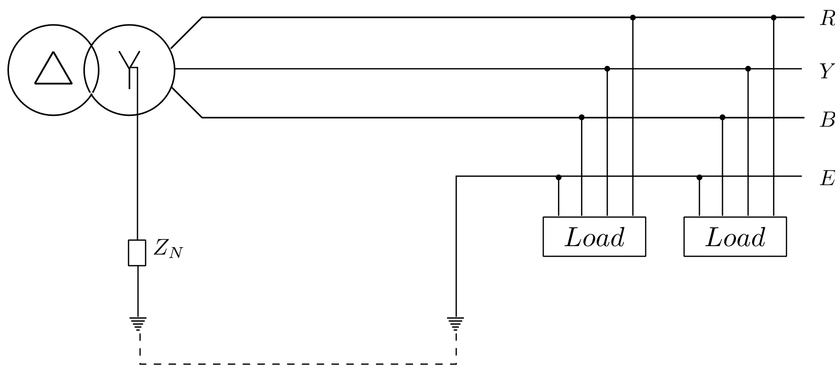

Figure 1: IT System

- A good level of network insulation is required (i.e the network must be broken up if widespread and the loads with high leakage current must be supplied by insulating transformers).
- Overvoltage limiters must be installed.
- All the installation's exposed conductive parts must be equipotentially bonded; else RCDs must be installed.
- The neutral should not be distributed due to the following reasons:

  - if the neutral conductor is distributed, a fault affecting it will eliminate the advantages attached to the IT system;

  - if the neutral is distributed, it must be protected;

  - the fact of not distributing the neutral facilitates the choice of overcurrent protective devices and fault location.
- Locating faults is difficult in widespread networks.
- When an insulation fault in relation to the earth occurs, the voltage of the two unaffected phases in relation to the earth takes on the value of the phase-to-phase voltage.

TT System (Directly earthed neutral)

First letter T implies that the neutral is directly earthed. Second letter T implies that the exposed conductive parts of the loads are interconnected either altogether or by a group of loads. Each interconnected group is earthed. One exposed conductive part can be individually earthed if it is far away from the others.

Advantages:

- This system is simple to design, implement, monitor and use.
- It does not require permanent monitoring during use. Only a periodic inspection test of the RCDs may be necessary.
- The presence of RCDs prevents the risk of fire when their sensitivity is below or equal to 500 mA.
- Faults can be easily located.
- Upon occurrence of an insulation fault, the short-circuit current is small.

Disadvantages:

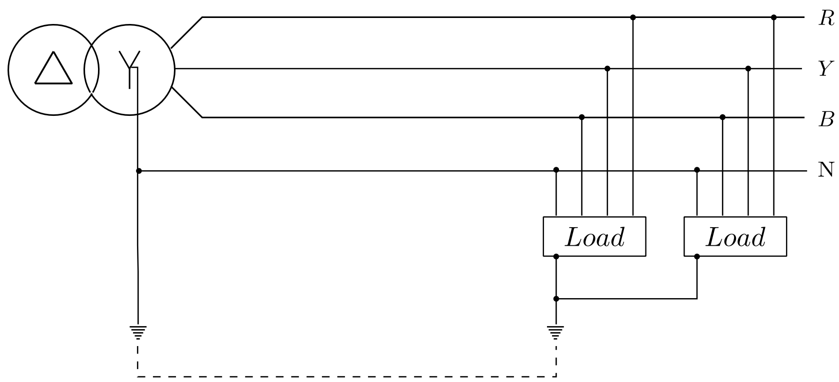

Figure 2: TT System

- Switching upon occurrence of the first insulation fault.
- An RCD is used on each outgoing feeder to obtain total selectivity.
- Special measures must be taken for the loads or parts of the installation causing high leakage currents during normal operation in order to avoid spurious tripping (feed the loads by insulating transformers or use high threshold RCDs).

TN System (neutral-connected exposed conductive part)

Letter T implies that the neutral is directly earthed. Letter N implies that the exposed conductive parts of the loads are connected to the neutral conductor. There are two types of systems, depending on whether the neutral conductor and protective conductor (PE) are combined or not:

Case 1: The neutral and protective conductors are combined in a single conductor called PEN. The system is identified by a third letter C and is called TNC. Earthing connections must be evenly placed along the length of the PEN conductor to avoid potential rises in the exposed conductive parts if a fault occurs. This system must not be used for copper cross-sections of less than 10 mm^2 and aluminium cross-sections of less than 16 mm^2.

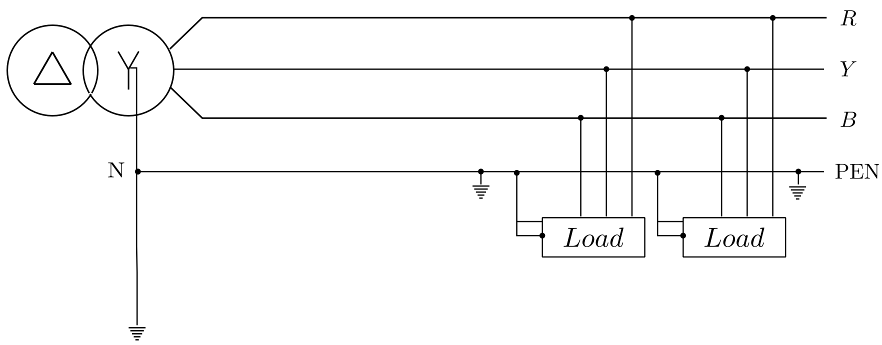

Figure 3: TNC System

Case 2: The neutral conductor and protective conductor are separate. The system is identified by a third letter S and is called TNS. Earthing connections must be evenly placed along the length of the protection conductor PE to avoid potential rises in the exposed conductive parts if a fault occurs.

Advantages:

- The TNC system may be less costly upon installation (elimination of one switchgear pole and one conductor).

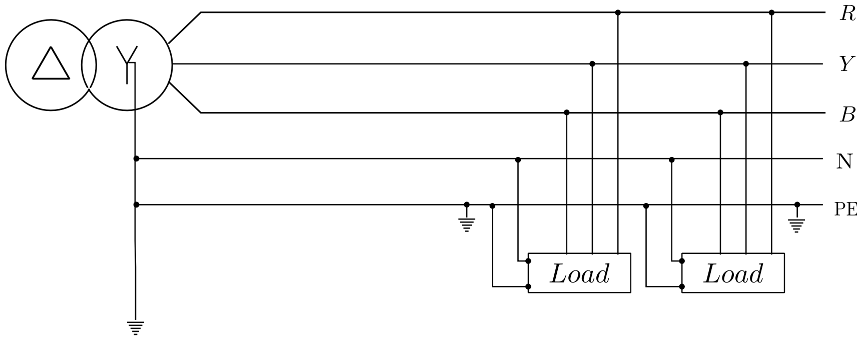

Figure 4: TNS System

- Overcurrent protective devices are used to ensure protection against indirect contact.

Disadvantages:

- Switching on occurrence of the first insulation fault.
- Earthing connections is required to be evenly placed in the installation so that the protective conductor remains at the same potential as the earth.
- Protective conductor is in the same trunking as the live conductors of the corresponding circuits.
- It often requires extra equipotential bonding.
- Third and multiples of third harmonics circulate in the protective conductor (TNC system).
- The fire risk is higher and therefore it cannot be used in places presenting a fire risk (TNC system).
- Upon occurrence of an insulation fault, the short-circuit current is high and may cause damage to equipment or electromagnetic disturbance.

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[1] Prévé, Christophe. *Protection of electrical networks*. John Wiley & Sons, 2013.