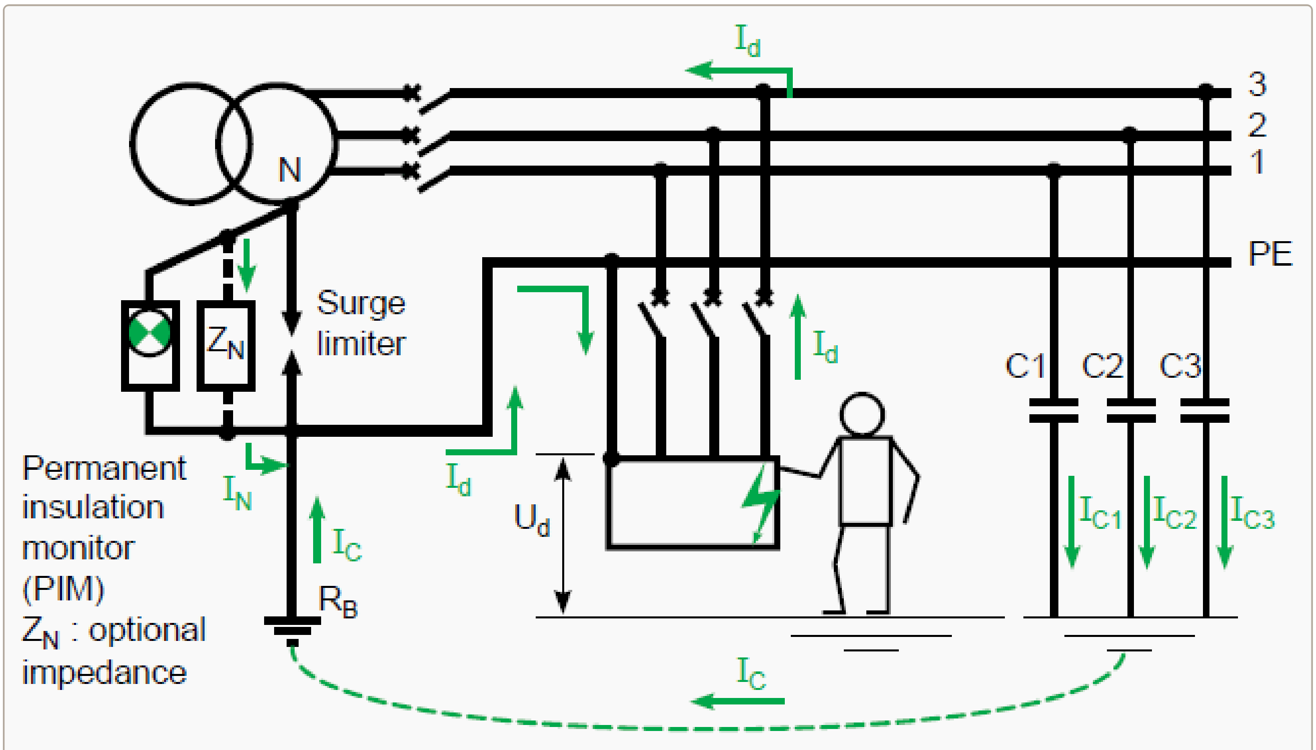
Overvoltages in the IT system

Edvard



Single insulation fault on a network operated in IT earthed system

Introduction to overvoltages

Electrical networks can be subject to overvoltages of varying origins. Some overvoltages, such as differential mode ones (*between live conductors*) affect all the earthing systems.

This section is particularly concerned with common mode overvoltages, which mainly affect the IT system as the network is then "***unearthed***":

1. Overvoltages due to insulation faults,
2. Overvoltages due to internal disruptive breakdown in the MV/LV transformer,
3. Overvoltages due to lightning striking the upstream LV network,
4. Overvoltages due to lightning striking the building in which the installation is housed.

These overvoltages are particularly taken into account by standard NF C 15-100 which stipulates installation of a surge limiter downstream of an MV/LV transformer and when there is a risk of lightning (overhead lines).

Overvoltages due to insulation faults

When the first insulation fault occurs, the phase-to-earth voltage of the sound phases is permanently brought to the phase-to-phase voltage of the network.

LV equipment must thus be designed to withstand a phase-to-earth voltage of U_{0e} and not the phase to neutral voltage U_0 for the time required to track and eliminate the fault.

This particularly applies to:
"Y" capacitive filters fitted on many electronic devices; installation PIM (***Permanent insulation monitor***) when

installed between phase and earth because the neutral is not accessible.

When choosing a PIM, it is thus important to verify the voltage of the network to be monitored declared by its manufacturer. These recommendations are specified in particular in standard ***IEC 60950***.

On occurrence of the first fault, a transient overvoltage appears with a possible peak of 2.7 x√U_0 (U_0 = phase to neutral voltage of the LV network). On a 230 V/400 V network, this value is 880 V, an overvoltage level that is not dangerous for equipment with an insulation of 1,800 V (voltage constraint at power frequency on the LV side as per ***IEC 60364-4-442***).

Note that these overvoltages do not cause permanent short-circuiting of the surge limiter.

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Overvoltages due to intermittent insulation faults

Intermittent faults (according to international electrotechnical vocabulary, or "***restricting***" or "***arcing***" faults in Anglo-saxon literature) behave like a series of transient faults.

Experience and theoretical studies show that intermittent faults can generate overvoltages and thus result in equipment destruction. Such overvoltages are particularly observed on MV networks operated with an earthed connection by a tuned limiting reactance (Petersen coil). These overvoltages are caused by incomplete discharging of zero sequence capacity on re-arcing.

The zero sequence voltage therefore increases each time the arc is ignited. Assuming that the arc is ignited at the highest value of the phase-to-earth voltage of the faulty phase, and zero sequence voltage increases each time, overvoltages of 5 to 6 times phase to neutral voltage may be generated.

Yet again, in the IT system, ***protection is provided by the surge limiter***, and presence of an impedance between neutral and earth encourages rapid discharging of the zero sequence capacity. Overvoltages due to internal disruptive breakdown of the MV/LV transformer Voltage withstand at power frequency of LV equipment is defined in standard IEC 60364-4-442 which specifies their values and durations (***see fig. 1***).

Internal disruptive breakdown between the MV/LV windings. This kind of overvoltage is at network frequency. These overvoltages are rare and their "***sudden***" appearance means that the surge limiter, whose certain arcing voltage is set at least at 2.5 times type voltage (NF C 63-150), i.e. for example 750 V for a limiter placed on the neutral of a 230/400 V network, immediately earths the LV network, preventing it from rising to MV potential.

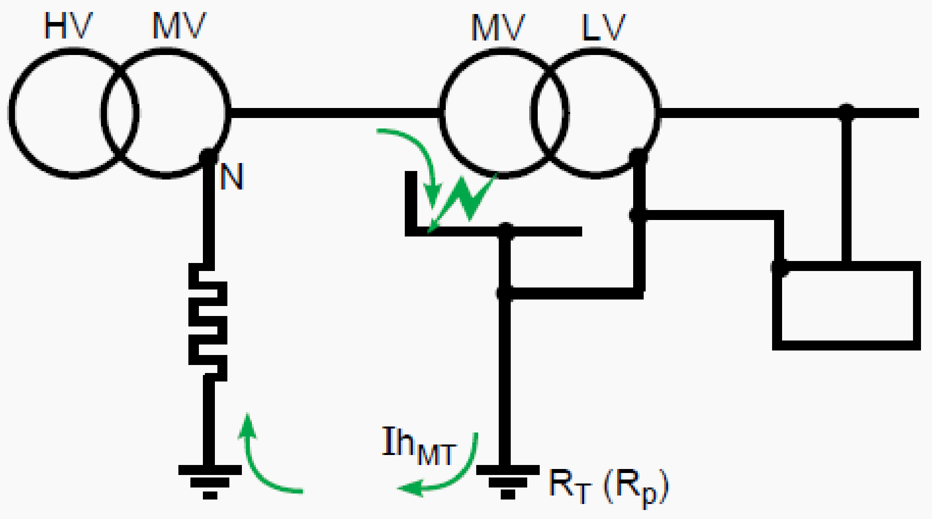

Figure 1 - When the substation frames (MV) and the PE earth connection (LV) are connected to the same earth connection, the LV load frames are brought to the potential IhMT Rp.

MV/frame internal disruptive breakdown also known as "***return disruptive breakdown***". When the transformer frame and the LV network are connected to the same earth connection (***see fig. 2***) there is a risk of LV equipment disruptive breakdown if the voltage $R_p\ Ih_{MT}$ exceeds equipment dielectric withstand, with R_p (earth connection resistance) and Ih_{MT} (zero sequence current due to MV disruptive breakdown).

One solution is to connect the LV installation frames to an earth connection that is electrically separate from that o the substation frames. However, in practice, this separation is difficult due to frame meshing in MV/LV substations. Consequently standard ***IEC 60364-4-442*** states that the LV installation frames can be connected to the earth connection of the transformer substation frames if the voltage $R_p \, Ih_{MT}$ is eliminated within the stipulated times.

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Overvoltages due to lightning striking the upstream MV network

When lightning strikes the MV network, a wave is transmitted to the live conductors on the LV side as a result of capacitive coupling between the transformer windings.
If the installation is in IT, the surge limiter absorbs the overvoltage occurring on the live conductor to which it is connected (neutral or phase) and is short-circuited if this overvoltage is very high: the network can then be compared to a network in TN-S.

Experience and measurements have resulted in the following observations:

- Overvoltages of around ***2 kV*** occur at the end of short cables (10 m) irrespective of load and earthing system.
- Higher overvoltages occur at the end of cables with open end or which supply loads likely to generate resonance. Even with a resistive load, overvoltages exist (***see fig. 2***), caused by wave propagation and reflection phenomena and by capacitive coupling between conductors.

In view of the waveform of these overvoltages, the surge limiter is effective on the conductor to which it is connected. Consequently, regardless of the earthing system, we strongly recommend that surge arresters be installed at the origin of the LV network, between all live conductors and the earth, if there is a risk of the upstream MV network being directly struck by lightning (case of overhead lines) and especially if the LV network is also at risk. The surge limiter continues to perform its function for MV/LV disruptive breakdown.

u (kV)	Ph/Ph	Ph/PE	Ph/N	N/PE	PE/deep earth
System:					
IT	0.38	4.35	0.20	4.30	1.62
TNS	0.36	4.82	0.20	4.72	1.62

Fig. 2 - overvoltages, caused by a lightning shock wave, measured at the end of a 50m cable supplying a resistive load.

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Overvoltages due to lightning striking the building housing the installation

These overvoltages are caused by lightning current flowing through the building’s earth connection, particularly when lightning strikes a building equipped with a lightning rod.

The entire earth network then markedly rises in potential with respect to the deep earth. The LV network, immediately earthed by the surge limiter, changes from the IT to the TN-S system if all the application frames are interconnected. The lightning energy thus flown off can be considerable and require replacement of the limiter.

In order to minimise these overvoltages on electrical installations, the building’s horizontal and vertical equipotentiality must be the best possible in low and high frequency. A single earth circuit (PE network) is naturally recommended, and use of metal cable trays with proper ***electrical connections (braids)*** is highly advisable for distribution.

Resource:

Schneider Electric Cahier technique no. 178 – The IT earthing system (unearthed neutral) in LV