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Automation Components

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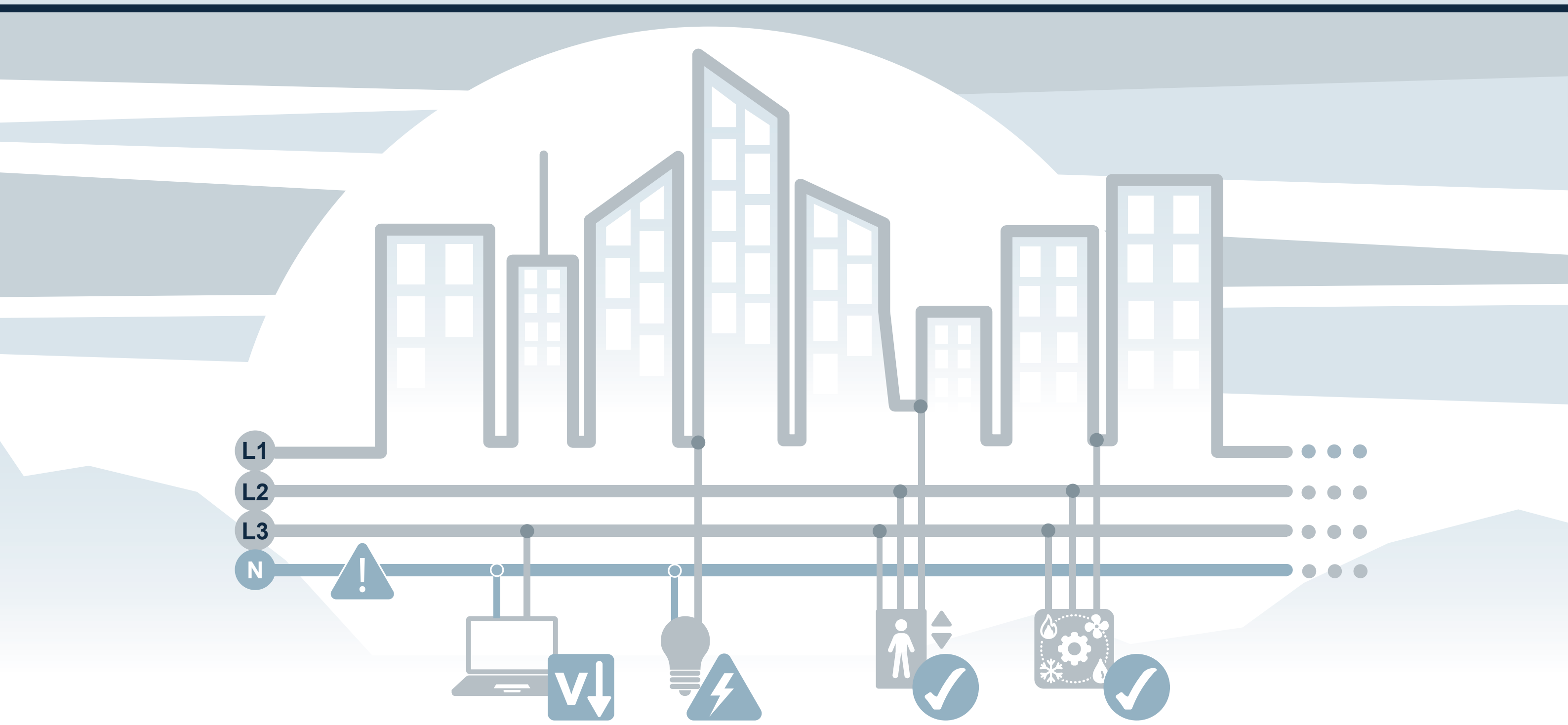
White paper



Phase or neutral loss in buildings

Trivial failures which may cause very expensive chain effects

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July 2021

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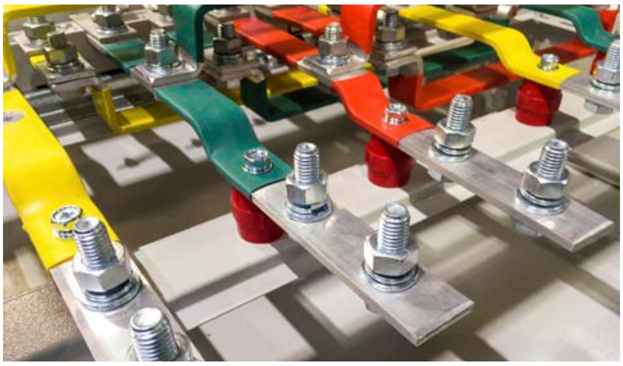
Trivial failures which may cause very expensive chain effects



INTRODUCTION

In our everyday's life we don't think of phase loss or neutral loss as situations which take place often, so we don't consider them a threat. Indeed engineers, who design electrical distribution systems for buildings, know the consequences of these failures and put in place actions to mitigate their effects. It all starts knowing how the system is set up (being a mix of 3-phase and 1-phase loads) and understanding what happens when the failure occurs. Most of the times it is caused by some other failure which leads to a blown fuse, even if there may be further reasons.

ABSTRACT

Phase and neutral loss can be very costly failures for the end user. We'll introduce some criteria and tools to reduce or clear their effects. After having a look at how electrical distribution systems are deployed, and at what happens in case of failure, we'll show how to use some tools to quickly detect them and react before damages occur. In this way the added value for the end user is huge in terms of Total Cost of Ownership (TCO) for the entire building.

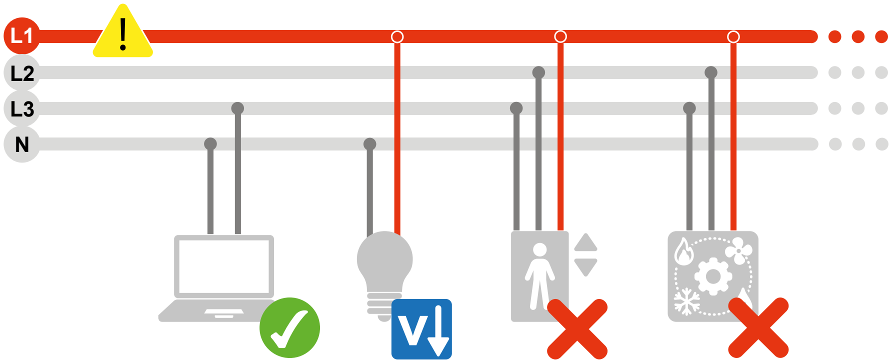
HOW ELECTRICAL ENERGY IS DISTRIBUTED IN BUILDINGS

Commercial buildings (like offices, shops and malls), as well as industrial buildings, are always supplied with a 3-phase connection from the grid. There are usually two types of load with different requirements when talking about the phase and neutral loss failures.

3-phase loads (motors): lifts, HVAC systems, fans, ...	These loads are connected to the 3-phase directly, or via a variable speed drive. They are balanced loads, so the current of the three phases is the same. There may be neutral connection for some of the auxiliary services (e.g.: controllers, lights) to slightly imbalance the load.
1-phase loads (lights, appliances, computers, fridges, vending machines, some of the kitchen equipment, ...)	These loads are all connected between one of the phases and neutral. The electrical installer, when deploying the system, estimates where the loads will be placed and designs it so that the loads on the three phases will be as balanced as possible (more or less the same current on all phases). The advantages are that the phase voltage imbalance is reduced (all the phase-neutral voltages are similar, which is very good for the 3-phase loads) and so is the neutral current. What happens when the system is up and running, is that the loads arrangement changes all the time, because loads are activated hectically, and new ones are added over time, so the phases balance set up initially may be quite reduced.

EFFECTS OF PHASE LOSS

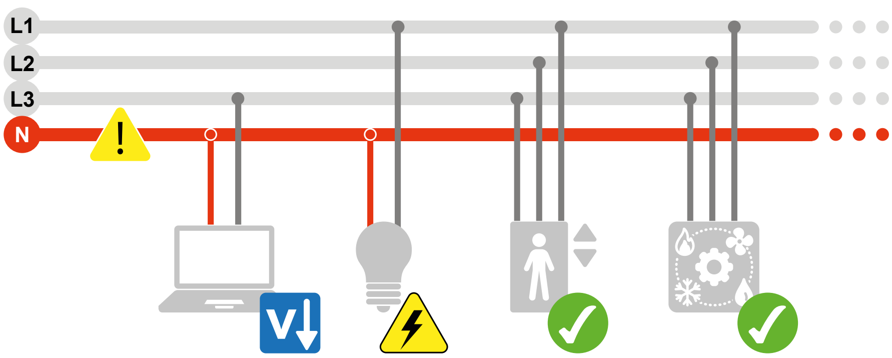
When phase loss takes place, one phase isn't connected to the generator side anymore. Its voltage against the rest of the system depends on the loads which are running at the moment of failure. The main players are the 3-phase loads, which may regenerate a certain voltage to the lost phase, depending on their status, which can be anywhere between 0 V and the nominal voltage against neutral. 1-phase loads connected to the lost phase are affected.



3-phase loads	They experience an extreme voltage imbalance, meaning quick overheating and thermal protection intervention. Motors don't start (they may keep on running under high stress), while inverters usually refuse to start. The examples in the picture are the lift and the air conditioning equipment.
1-phase loads connected to the lost phase	They face a serious undervoltage. They may not start, or switch off, or overheat some of their parts. In our case the lamp may not turn ON or just glow.
1-phase loads connected to the remaining phases	No issue. This is important, because they keep on working, safeguarding some of the functions of the building (e.g.: residual illumination). This is what happens in figure to the PC.

AN INSIDIOUS FAILURE: NEUTRAL LOSS

When neutral is disconnected, the situation is more subtle, and depends on the imbalance of the system caused by the running 1-phase loads. If the three phases are perfectly balanced (all the loads on the three phases are the same) nothing happens, and all voltages and currents remain the same. On the opposite side, if the imbalance is total (almost all 1-phase loads on one phase and no 3-phase loads), there is an overvoltage on the remaining two phases (i.e.: moving from 230V to 400V in most of the European countries) and this causes failure of 1-phase loads connected to them, and potentially fire. No voltage is present on the heavy loaded phase. All the other cases are somewhere in the middle, so there is undervoltage on one or two phases and an overvoltage on the remaining ones. Both effects are dangerous and may generate overheating and fire. In the example, the lift and the air conditioner work fine (3-phase loads), the PC may not turn on. The worst situation is on the lamp, which fails. Some equipment may even catch fire.



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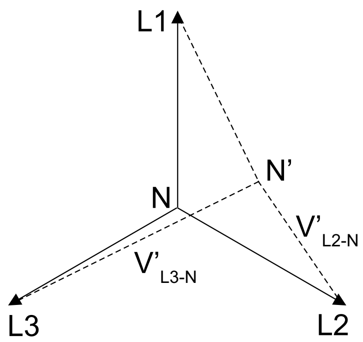
NOT TO FORGET ABOUT PHASE IMBALANCE

Phase and neutral loss are just extreme cases of phase voltage imbalance. Yet there is no need to lose a wire to get imbalance. The most common cause of it in buildings is that new 1-phase loads are added over time to the system, and there is no control on which phase they end up being connected. Furthermore, they are randomly ON and OFF, causing imbalance.
To mitigate these effects, the solution is to use a voltage imbalance relay (also called asymmetry). When it trips, a re-arrangement of the loads across the phases can be evaluated, planned and execute at a time when the effect of mains interruption is smaller.



$$\max |\Delta V_{PH-N}| = |V'_{L3-N} - V'_{L2-N}|$$

$$\max |V_{\lambda NOM} - V_{PH-N}| = |V_{\lambda NOM} - V'_{L3-N}|$$

Mains type	Voltage asymmetry (%)
3P	$\frac{\max \lvert\Delta V_{ph-ph}\rvert}{V_{\Delta NOM}} \times 100$
3P+N	$\frac{\max \lvert\Delta V_{ph-n}\rvert}{V_{\lambda NOM}} \times 100$

THE CARLO GAVAZZI SOLUTIONS

Protecting from phase loss damages

SOLUTION	DPA51CM44 is a phase sequence and loss relay. It detects incorrect rotation direction of motors (two wires accidentally swapped) and when a phase is lost. In this case the detection works even when the voltage on the lost phase is regenerated by the load to a value quite close to the nominal one. It doesn't need any setting and it is just 17.5 mm wide, to save electrical panel space and to be installed in the typical building distribution panels. When phase loss occurs the relay trips. What most often happens is that the load is disconnected.
ADVANTAGES	• Plug&play • Multivoltage • Suitable for building energy distribution panels

Suggested device	DPA51CM44
Standard function	Detect when a phase is lost even if regenerated voltage is present.
Main purpose	Protect the 3-phase loads from severe imbalance and overheating. Protect 1-phase loads from undervoltage and malfunction.
Addressee of the notification	Disconnect the circuit or inform the main controller to switch off the related loads.

Protecting from neutral loss damages

SOLUTION	DPB51CM44 adds overvoltage and undervoltage to the features of DPA51CM44. When neutral wire is connected, the measure is made on all phase-neutral voltages. This adds detection of the effects of neutral loss to disconnect the loads in case of danger. In this case, beyond disconnection, the engineer can decide to inform the Building Management System to elaborate an emergency plan.
ADVANTAGES	• Plug&play • Multivoltage • Suitable for building energy distribution panels

Suggested device	DPB51CM44
Standard function	Detect neutral loss through measurement of the phase neutral voltages: if out of tolerance the relay trips.
Main purpose	Protect 3-phase loads from severe imbalance and overheating Protect 1-phase loads from undervoltage and malfunction.
Addressee of the notification	Disconnect the circuit or inform the main controller to switch off the related loads.

Protecting the loads from voltage asymmetry (imbalance)

SOLUTION	DPB02CM23 and DPB02CM48 (208-240 V and 380-480V respectively) provide the same as DPA51CM44 and an accurate metering of the phase imbalance to inform the facility manager and plan the corrective action (move loads across the phases) when it is less impacting.
ADVANTAGES	• Reduce the Total Cost of Ownership of the connected equipment

Suggested device	DPB02CM23, DPB02CM48
Standard function	Detect phases imbalance.
Main purpose	Avoid prolonged overheating of 3-phase loads causing shorter lifetime.
Addressee of the notification	Inform the main controller to plan system re-balance at the next appropriate time.

CONCLUSIONS

The impact of phase and neutral loss in buildings may be catastrophic (fire) or, in the best case, very expensive to recover (maintenance of equipment or even its replacement). These events may occur just after a trivial blown fuse and aren't as rare as we often expect. Protecting the building from them implies a small investment in terms of components, installation, and space, while providing huge Total Cost of Ownership improvement for the building owner.

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WP Phase or neutral loss ENG REV.00 07/21