Power Frequency Overvoltage. EN50550 Standard
"Power Frequency Overvoltage Protectors (POP)"

Cirprotec Technical Article No. 8

0. Introduction

EN50550, published on March 16, 2011 is the first **European standard for power frequency overvoltage protection (POP)**, also known as permanent overvoltage and temporary overvoltage (TOV) depending on the country and language. From this point forward, the article will refer to "power frequency overvoltage" and "POP devices".

Installing a protection against these was already mandatory in Spain, and thus the European standard normalises and standardises the range of solutions in the market to date. In this sense, the EN50550 standard sets the **quality standards** that the market deserves and sets the **technical parameters** that must be complied with to **ensure protection and reliability while avoiding** unnecessary service interruptions.

Cirprotec, global leader in the overvoltage sector, has worked together with different regulatory groups to draw up this standard, contributing its technological and applied know-how.

The following article explains the issues surrounding power frequency overvoltage (POP). First, the technical characteristics are presented, followed by an explanation of the causes of this type of overvoltage. Then, there is an account of the results of the analysis of overvoltage effects on electrical equipment connected to the mains network. These results stem from our experience in the market and the tests performed at LRIC. Lastly, as regards commercial solutions, it details the requirements set out by the EN50550 standard about protection devices, that is, Power Frequency Overvoltage Protectors (POP).

1. ¿What are power frequency overvoltages and how are they different from transient overvoltages?

The implementation of both surge protection and power frequency overvoltage protection has remarkably increased in recent times, mainly due to two factors: The profusion of electrical and electronic equipment which is increasingly sensitive to such issues, and the proliferation of new standards and regulations which standardise and even require the installation of this type of protectors.

Overvoltages are voltage increases which damage electrical equipment connected to the mains network. In some cases, the equipment is destroyed instantaneously, and in others it causes its gradual deterioration, thus reducing its lifetime.

There are two types of overvoltage: **transient and power frequency overvoltage**. Both mean an increase in voltage, but they are different as regards cause, magnitude, duration and protection technique. Thus, the concept for comprehensive overvoltage protection has to take into consideration at least: transient overvoltages and power frequency overvoltages.

To put into context the phenomenon which is the object of this article here is an overview of what transient overvoltages are.

Transient overvoltages are voltage spikes reaching values of tens of kilovolts with a duration of microseconds.

This type of overvoltage can have various different causes, including atmospheric lightning directly striking the external protection (lightning rod) on a building or transmission line or the associated induction of electromagnetic fields on metallic conductors. It is also common for non-weather phenomena, such as transformer centre switching or switching of motors or other inductive loads to cause voltage spikes in adjacent lines.
Transient overvoltage is not exclusive to power distribution lines but is also common in any line made of metal conductors, such as telephone, communication, measurement and data lines.
In all these networks, surge protection is achieved by installing the protector or **line discharger** on the line likely to receive the overvoltage, connecting it in parallel between the line and earth. This means that in the event of a transient overvoltage, the protector **will discharge excess energy to earth, thus limiting the peak voltage to a value acceptable** for the electrical equipment connected.

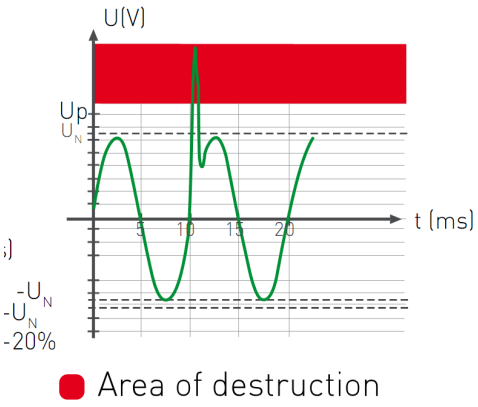


Figure 1. *Phase imbalance chart*

Power frequency overvoltages (POP) are any voltage increases above 20% of the effective nominal value **for an indefinite period**. Power frequency overvoltages are caused by supply problems, or, very often, by bad connections or breakage of the neutral conductor. They can also be caused by anomalies in the power supply.

Most power distribution systems use a neutral conductor (usually grounded) which acts as a reference for the phase voltages. A return current runs through this conductor, which enables effective voltage to remain constant between each of the phases and the neutral (single-phase voltage). Thus, if the conductor breaks, single-phase voltages become unbalanced: The voltage received by any system connected between phase and neutral is floating and depends on the load imbalance on the three-phase network. When this happens, some users can receive as much as 400 effective Volts instead of 230 V. An increase in effective voltage may lead to premature aging of receivers, current increases or even their destruction, with the resultant fire risk.

Figure 2 shows how neutral cable breakage causes phase imbalance. The neutral cable is grounded at the transformer substation. When it breaks, the grounding reference is lost and the 3 fixed voltages of 230 Vac, with a 120° imbalance between them, become floating voltages and their value depends directly on the mains load. The phase with the highest connected load will receive an undervoltage (line 1 in Figure 2). The phase with the lowest connected load will suffer the greatest increase in voltage (line 2 in Figure 2). This power frequency overvoltage can reach 400 V if the network is very unbalanced.

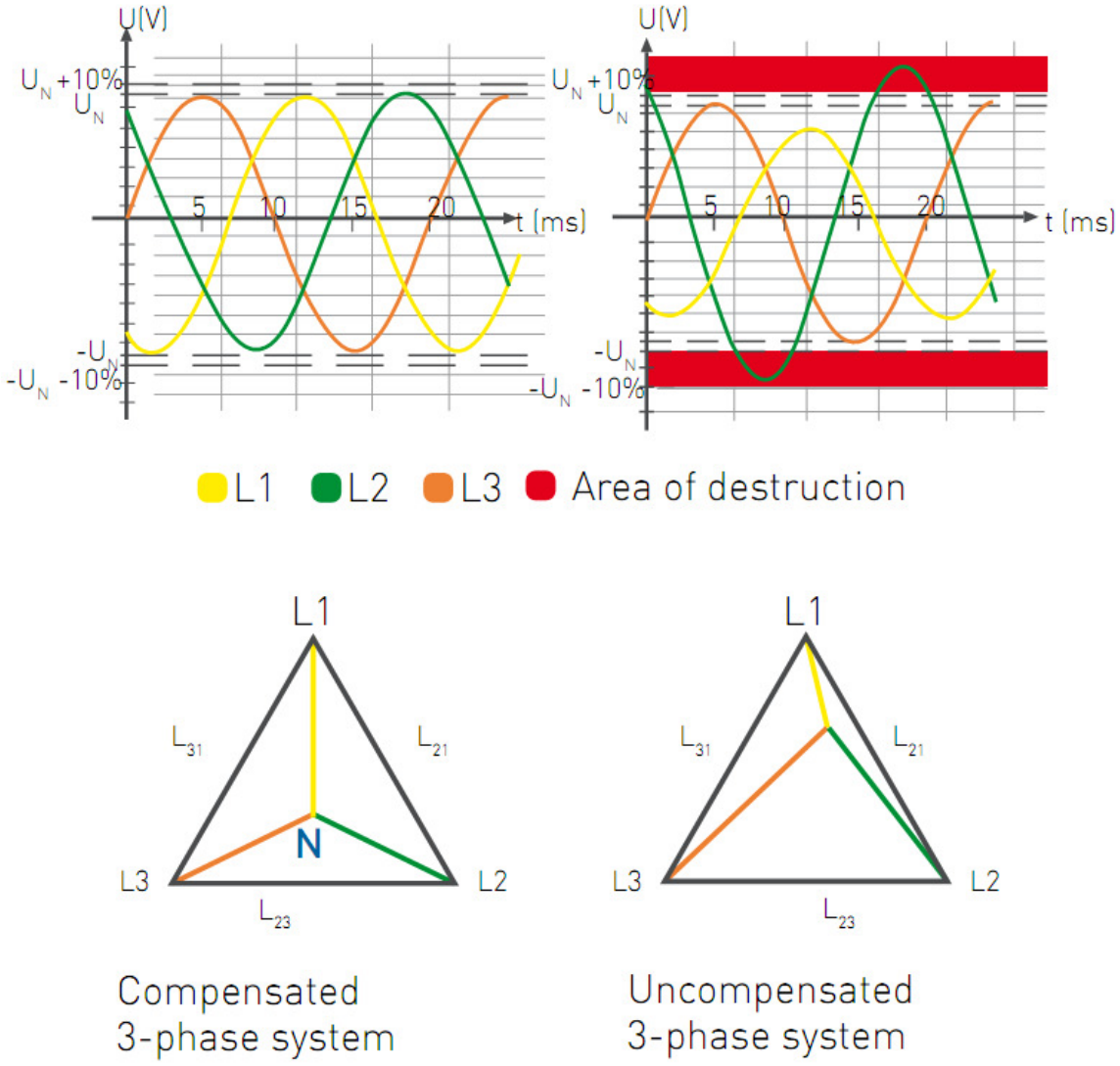


Figure 2. *Phase imbalance chart*

Power frequency overvoltage protection consists in monitoring each of the voltages and tripping a cutout device if voltage increases above 20% of the nominal value. The cutout device trips faster in the event of higher overvoltages.
The new **EN50550** standard determines the mandatory specifications of power frequency overvoltage protectors and the progressive voltage/time tripping curve. This standard ensures protector quality and the proper protection of the equipment.

Additionally, to ensure that power supply is restored immediately after restoration of the normal operating voltage, there are commercial solutions which include a safe automatic reclosure system, generally based on a motorised MCB with a reconnection procedure that goes beyond a mere delay.

In industrial environments, the best practice is to divide the system into sectors to prioritise service continuity. The protection is not required in systems where the power distribution has no neutral (voltages cannot be unbalanced), such as motors, or when exposed equipment is more sturdy. In these environments, the POP device focuses on prioritising electrical safety in industrial control areas, which frequently have extremely sensitive, expensive equipment.

A further clarification about power frequency overvoltage is that surge protection devices (SPDs) include in their specifications a TOV resistance value against power frequency overvoltages that stem from various different causes. However, this value is a self-protection measure of the SPD which lasts only for a few seconds and does not ensure immunity, but an ordered end of life. Naturally, it does not give the SPD any capacity to protect equipment on the network against power frequency overvoltage.

“Permanent” undervoltages are power frequency undervoltages which can also be very dangerous in systems where there is equipment such as engines or compressors (inertial), since they require energy which is no longer available and system control is lost. Moreover, servers or data storage systems are very sensitive to voltage, and can suffer data loss when these anomalies occur. The required protection is essentially the same as the one used for power frequency overvoltage (POP).

2. Consequences of power frequency overvoltages (POP) on equipment

Power frequency overvoltages (POP) can cause many different problems, which basically depend on the degree of overvoltage and load sensitivity. The most immediate result of power frequency overvoltages is the **destruction of equipment connected to the network**. Equipment can be destroyed at once if the overvoltage is high, or it can be worn out due to the fatigue of electric insulators, which results in **reduced equipment lifetime**. The destruction can start a fire in the equipment without causing an overcurrent. Thus, automatic circuit breakers will not cut the supply and the fire will spread to the rest of the system, **which can cause damages to persons and property**.

Cirprotec has carried out a **study** at its **independent test lab (LRIC)** with the aim of determining the **sensitivity of electric and electronic equipment** when faced with **power frequency overvoltages (POP).** We have also tested how long this equipment can withstand a power frequency overvoltage, with the aim of determining the actuation time of a power frequency overvoltage protector to ensure the safety of the protected equipment.

Figure 3a. *Desktop computer power supply tested at LRIC*

Figure 3b. *15 W energy-saving bulb tested at LRIC*

Power frequency overvoltages cause the destruction of equipment connected to the network

The study applied power frequency overvoltages to electrical equipment of well-known brands, lesser-known brands and “branded labels”. To obtain a statistically relevant sample, part of the equipment was new and part of it was used (always older than 2 years).

Specifically, the experiment consists in **studying the behaviour in the face of power frequency overvoltage of** computers, power supplies, household devices (e.g., air fresheners and DVD players), terminal strips with surge protection, the network analyser and bulbs (e.g., energy-saving, fluorescent with and without electronic ballast, halogen, high pressure sodium bulbs and LED traffic lights). *Figures 3.a* and *3.b* show different equipment after conducting the tests.

In the experiment, **power frequency overvoltage pulses** have been the cause of the **fault** in **41.5%** of **tested equipment**. When the **overvoltage lasts for a long time**, the percentage of faulty equipment reaches **69.7%**.

The results of the study lead to the conclusion that the internal components of the equipment which were more sensitive to power frequency overvoltage are **fuses, transformers, condensers and varistors**, and that the fact that it is used equipment is particularly relevant when exposed to a long-duration power frequency overvoltage. The vast majority of equipment with electronics, such as household appliances, computers, and industrial control equipment contain these components.

These tests have been used to **design the progressive voltage/time tripping curve of protectors** and **adapt tripping time to the EN50550 standard**, ensuring the protection of the equipment and avoiding unnecessary service interruptions.

Power frequency overvoltages bring about excessive current and higher electricity bills

Additionally, **power frequency overvoltages** cause other problems before the equipment is destroyed. Increased nominal voltage implies greater current in resistive loads, and this causes **overheating**, **higher electricity bills and the deterioration of the equipment**. Increased current causes the overvoltage to increase to the square. For instance, a 20% voltage increase entails an increase of almost 45% in the required power, which has a huge impact on the electricity bill.

3. The new EN50550 standard

The aim of standards is to unify the criteria of regulatory groups in different countries with the aim of:

- **Defining optimal, reliable protection methods**.
- **Ensuring high standards of quality for protectors**.
- **Defining minimum technical specifications for protectors.**

Innovation in protection development is always one step ahead of standardisation. For this reason, and despite countries such as Spain where the installation of power frequency overvoltage protectors has been mandatory for years, the first European standard, EN50550, was not published until 16 March 2011.

To guarantee the quality and reliability of power frequency overvoltage protectors (POP), **the EN50550 standard defines** that the following points must be complied with:

- **Common manufacturer of the power frequency overvoltage protector and the cutout device (usually the general automatic circuit breaker in the system).**
- **Prohibition on using earth leakage or current differential as operating principles.**
- **Classified as Class III: the protector must withstand a pulse voltage of 4 kV.**
- **Pass the electromagnetic compatibility tests**

Additionally, **the standard defines a progressive voltage/time tripping curve** (see Figure 4). The tripping time depends on the magnitude of the overvoltage, ensuring a faster response time in the event of higher overvoltages.
Thus, a dual objective is achieved: **Ensuring quick tripping in the case of severe disturbances** and **avoiding untimely tripping before small increases in voltage**.

The need for protectors complying with **EN50550** is the only way to **guarantee the safety and the proper protection of equipment**.

In fact, as with circuit breaker overcurrent protection and earth leakage protection, the only device which **guarantees 100% protection** in all circumstances against power frequency overvoltages is precisely the **POP device, rather than an over- or undervoltage relay.** Relays can be used for control, but not for protection against overvoltages, earth leakages or overcurrents, since they do not ensure a reliable tripping time. That is, relays are not protectors. This is directly related to the requirements about elements such as tripping curves and electromagnetic compatibility tests in the EN50550 standard.

You can find more information at
www.cirprotec.com/EN50550

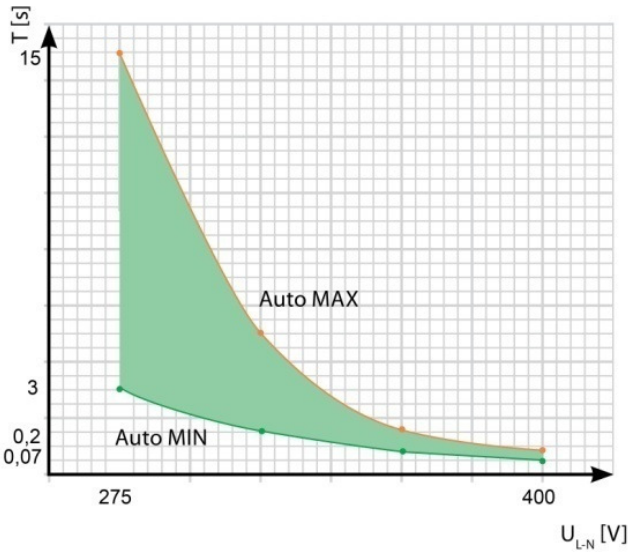


Figure 4. *2 tripping time curves depending on the overvoltage value*

4. OVERCHECK line control unit

CPT Cirprotec, a specialist in manufacturing lightning and surge protection, presents its new **Overcheck** range to control and protect the mains network, which stands out with its new compact design and state-of-the-art features.

Overcheck devices provide protection against:

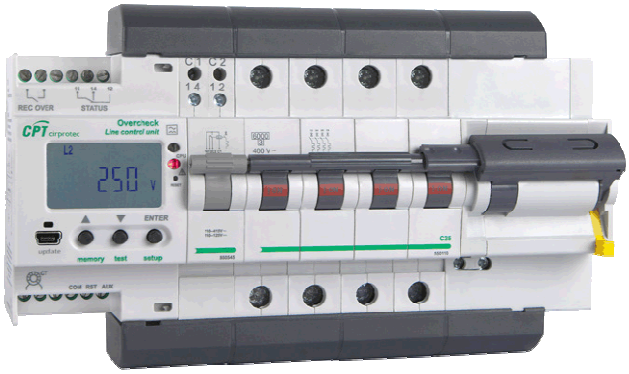
- Power frequency overvoltages and undervoltages according to EN50550
- Phase sequence errors.
- Earth leakages (Class A differential)
- Overload and short circuit (single- and three-phase automatic circuit breaker up to 63 A).

Overcheck is programmable: All protection parameters can be configured. It includes an end-of-reconnection-cycle alarm, a circuit breaker status alarm and a memory with historical fault log by type and date.

Overcheck is "self-reclosing": In the case of over- or undervoltages, the device reconnects safely once the situation has cleared. If triggered by the tripping of the automatic circuit breaker or earth leakage device, this product offers reconnections which can be customised by number and delay.

Of note among its new features is the software update via a mini-USB port, an expansion port for add-on modules and the option to block it using a PIN code.

It is a compact, fully pre-wired and easy-to-install DIN rail device.



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4. - Lightning and surge protection in schools.
5. - Lightning and surge protection in waste water purification plants.
6. - Lightning and surge protection in the AHIS (Automatic Hydrological Information System) network.
7. - Lightning and surge protection in BANKING PREMISES
8.- Power frequency overvoltage. EN50550 standard “Power Frequency Overvoltage Protectors (POP)”