

Electrical installation testers: CAT IV or CAT III?

This article helps to better understand dangers for the users of electrical installation testers caused by overvoltages and high current breakdowns. Protective measures against these phenomena are explained. Classification of the overvoltage protection level according to the international standard IEC/EN 61010-1 is explained and described.

Dangers for the electrician

Many dangers can appear on electrical installations.

The most known are:

- Electric shock caused by a direct contact with mains voltage.
- Electric shock caused by leakage current if touching a conductive part under voltage.
- Fire hazard and burnings because of overheating.

This document describes two less known, but also big dangers:

- Transient overvoltages (fast transients and surges).
- High (current) energy breakdowns.

Both, breakdowns and overvoltages are more likely to occur:

- On installations that are delivering more power (usually near the origin).
- On outside conductors that are more susceptible for all kinds of electromagnetic disturbances.

How transients and surges occur?

Fast (impulsive) transients

We all know how dangerous a stroke of lightning can be for electrical equipment.

Transients caused by lightning are a normal phenomenon on outside conductors. Very high voltage transients can occur – even up to several 10,000 volts!

Note that most lightning transients are not actually the result of direct lightning strikes. They often induce onto conductors as lightning strikes near the power line. The large electric field generated during a discharge can couple even in underground conductors.

This type of transients is definitely the most dangerous one. A powerful lightning stroke can provide a peak current of 85 kA and can last several hundreds milliseconds.

Surges (oscillatory transients)

High overvoltages (surges) occur because of fast current changes/interruptions in the power system. In general they have lower amplitude, but are more frequent than fast transients.

Common surge sources are:

- Fast current changes in inductive devices (switching on/off motors, transformers, large loads) during normal power system operation. In domestic installations surges can be generated while switching on/off lights. The surges spread through the installation wiring and result in flickering of TV signals, radio signals, etc.
- Uncontrolled switching on/off of the power system (failures, reaction of protective devices).

For large inductivities involved the transients are likely to exceed several 1,000 Volts, according to the equation:

$$U_i = L \, di/dt. \quad \text{Eq.1}$$

It must be stressed that as the number of installed electrical equipment increases the probability of surges and transients on power lines grows too.

In general the number of transients is higher and they are more dangerous closer to the utility side than in the domestic environment. Due to low line and loop impedances on the utility side the transients can travel on long distances along the conductors very easily and with low losses. Note that overvoltage events on the high and medium voltage system are reflected (transformed) to the low voltage side.

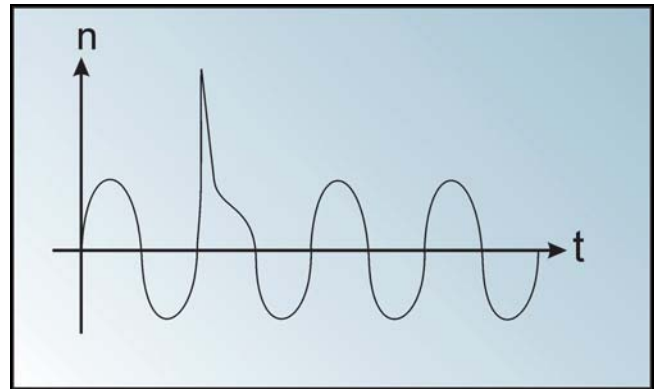
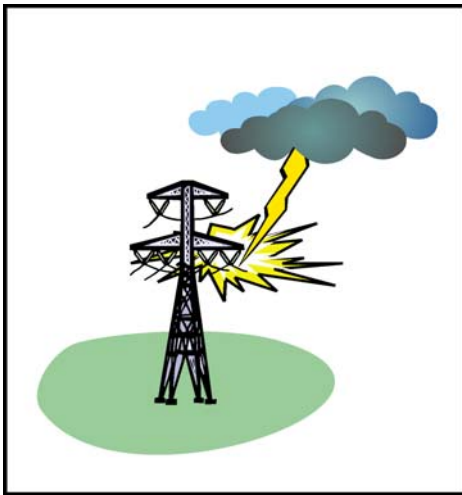


Figure 1: A fast transient caused by lightning

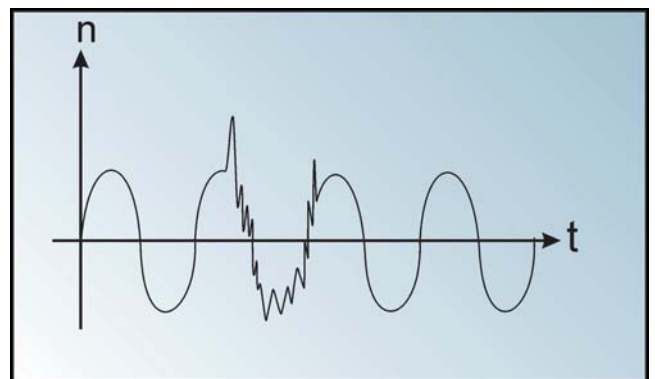
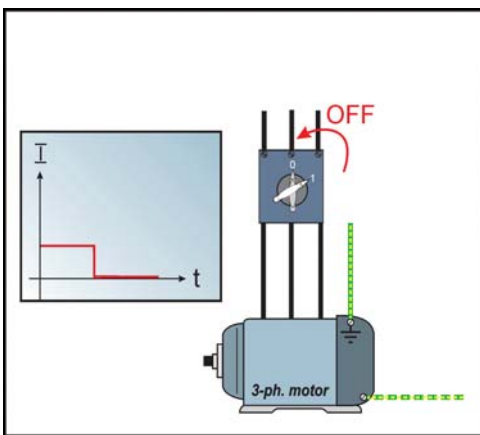


Figure 2: A surge on mains voltage as a result of switching off a large load

How high energy breakdowns take place?

High transient/surge voltages can provoke breakdowns of all kinds of electrical equipment.

A breakdown can occur:

- Wherever the electronics cannot sustain the voltage of a transient/surge.
- In case of improper insulation (damaged or stressed insulation, too small creepage and air distances).

The transient/ surge voltage acts as a trigger or ignition for the breakdown. What happens next depends on the installation impedances and fault impedance.

In a domestic environment breakdowns usually cause the tripping of protective devices without making serious problems.

At the origin of installation a breakdown can have more severe consequences. Why?

Loop impedances at or close to the transformer stations and power utilities are very low. This is because the energy must be delivered to the consumers with minimum losses.

As a result, at least at the first moments of a breakdown, there is nothing to stop the currents which can reach several thousands amps.

The breakdown point has a relatively high resistance compared to other wiring so a lot of energy ($I^2 \cdot R \cdot t$) is concentrated on it until it stops. The energy converts into heat – this usually results in blue light flash, local explosions, arcing. The arcing causes ionization of the air and is relatively difficult to stop. The temperature of the arc can reach up to 6000° K. This can cause burnings and severe damage all around the fault.

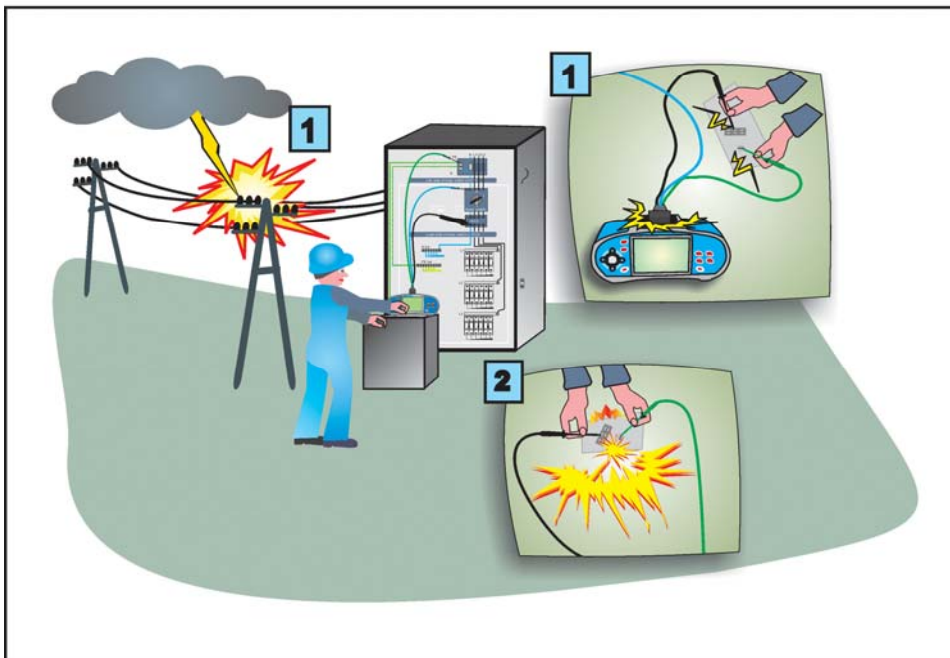


Figure 3: Example of a high current breakdown

How the standards deal with overvoltages?

The basic standard for electrical installation IEC/EN 60364 includes the definition of overvoltage categories in chapter 44 (Protection against voltage disturbances and electromagnetic disturbances). According to the installation impedances, proximity to the origin of the installation and installed protective elements, it classifies four overvoltage categories. For each declared category/voltage the maximum size of transient voltages to be expected during the measurement (on electrical installation, equipment, etc.) is defined.

All equipment must at least fulfill the protective measures for the category they are installed in.

Fig. 4 includes a graphical presentation.

The basic standard for safety of measuring equipment IEC/EN61010-1 also considers overvoltages. The minimum protective measures for measuring equipment for all installation overvoltage categories are defined. The measuring instruments should stay safe if they are exposed to the maximum expected transient voltage on the installation. A higher declared protection class and/or voltage means a higher protection degree of the measuring instrument.

Overvoltage protection categories (as defined in IEC/EN 60364)

CAT IV environment

A transient can spread through the low impedance wiring at the origin of the installation to the distribution boards with low losses. Connected loads are high, outside wiring is susceptible to lightning. Therefore the risk of occurrence of dangerous transient voltages and surges is very high.

Origin of installation, utility transformers, all outside conductors, counters, protective devices on primary sides and electricity meters are classified as CAT IV environment.

CAT III environment

Elements (fuses, switches, etc.) and branches in the distribution boards damp the amplitude and energy of the transient/surges from both sides. The wiring impedance between the utility and the distribution board helps to damp the transients too.

Distribution boards, machinery, main switching devices close to the switchgears, industrial installations and high current circuits/outlets close to the DB are classified as CAT III environment.

CAT II environment

The transients are further damped in the wiring inside the building. All circuits are fused with circuit fuses.

Outlets, lighting switches and connections in buildings and outlets at a distance more than 10 m from a CAT III source are classified as CAT II environment.

CAT I environment

On the electrical equipment side end the lowest transients are to be expected.

Electronics on secondary side of supply transformers, electrical equipment with supply voltage separation and low voltage outputs are classified as CAT I environment.

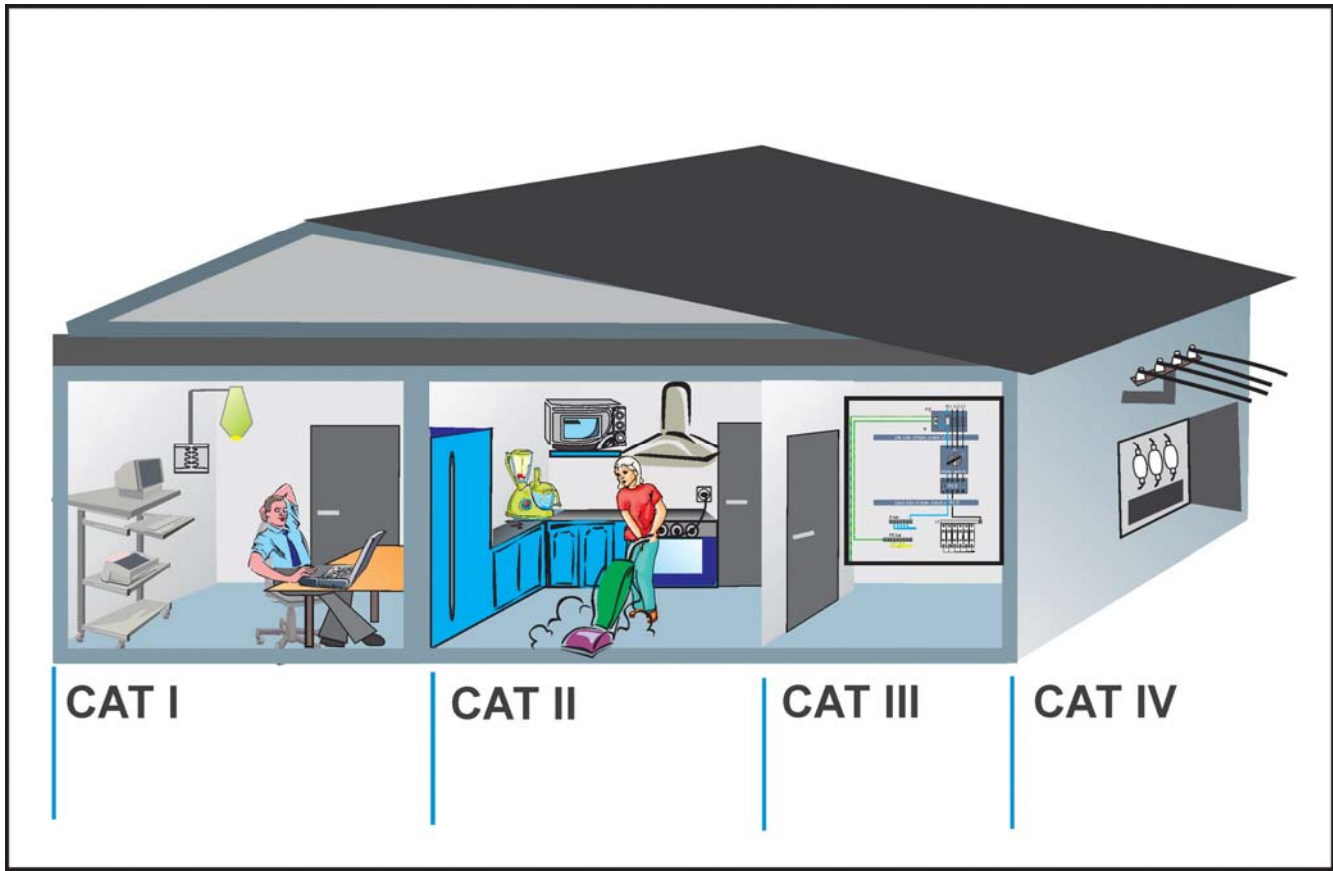


Figure 4: Class I to Class IV environments according to IEC/EN 60364

Overvoltage categories and electrical installation testers

Most installation testers are designed to sustain overvoltages expected in CAT III environment. Only few models with improved protection circuitry are designed for CAT IV environment.

Table 1 shows the transient test voltages for different overvoltage categories/working voltages.

Overvoltage protection category as defined in IEC/EN 61010-1 for phase – earth	Transient test voltage
CAT II 600 V	4000 V
CAT III 300 V	
CAT III 600 V	6000 V
CAT IV 300 V	
CAT III 1000 V	8000 V
CAT IV 600 V	

Table 1: Overvoltage protection categories

Protective measures in installation testers:

The users of installation testers are daily exposed to overvoltages. Especially if working in CAT IV environment the overvoltages can be high, dangerous and unpredictable.

The users often wear the instrument around the neck or in the hands during the measurements.

This is a very inconvenient situation if a breakdown occurs.

When a breakdown takes place, a lot of energy is concentrated on the instrument and accessories contact points because of their contact resistance. If the user tries to remove the leads during a breakdown, the arc and local burnings can even intensify (figure 3 – 2)

Higher overvoltage protection of the measuring instrument would therefore always be an advantage.

An instrument with a higher overvoltage protection will have:

- Higher creepage and air (clearance) distances on PCBs.
- Higher creepage and clearance distances on the measuring connections.
- Higher creepage and clearance distances between live parts (with applied mains voltage) and accessible conductive parts/openings in the enclosure.
- Additional protective elements (surge arresters, varistors, serial impedance, fuses) in order to damp eventual overvoltages and limit breakdown currents.

Thus, for an instrument with a higher protection class, transients and surges must have a higher amplitude to provoke a breakdown.

It can be concluded that a lot of additional protective measures are taken in measuring equipment with a higher overvoltage protection.

An experienced and skilled user would always decide for a tester with a higher protection degree.

Other safety considerations

Beside using a high protection class-measuring instrument, the user must also take care of the accessories (test leads, tips, crocodiles, clamps), especially if performing tests in a CAT IV environment. The accessories should be at least of the same category as the equipment.

Since accessories are more subjected to wear, damage, etc. it is good practice to use accessories with a higher protection class than the instrument.

Although considering all safety precautions the test equipment can still fail (breakdowns through unexpected transients, etc.).

Therefore the user:

- should wear insulated gloves, safety glasses, flame resistant clothes,
- should wear insulated boots and stand on unconductive floor,
- should not wear metal jewellery, watches,
- if possible the instrument should not be worn around the neck or in the hands,
- if in doubt, one should always assume that the circuit is live,
- etc.

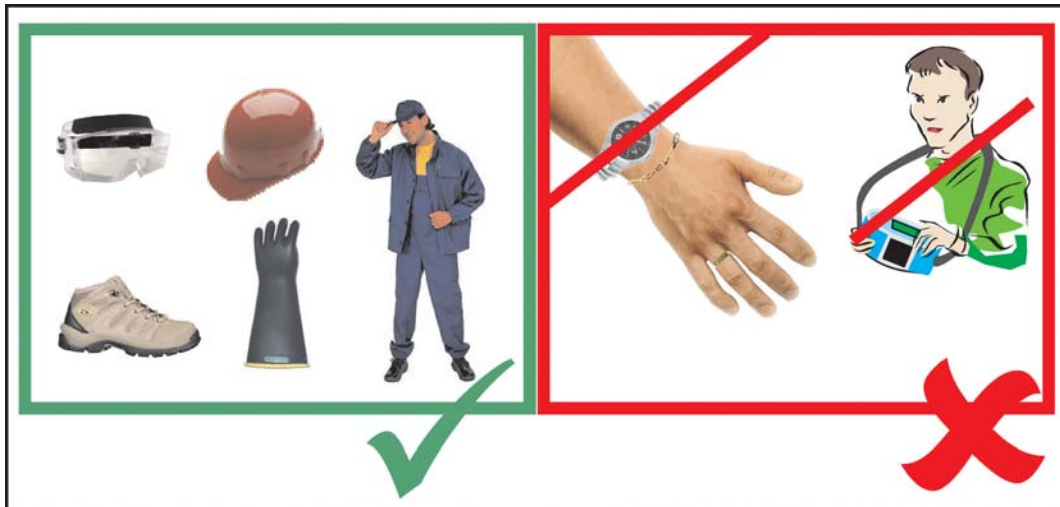


Figure 5: Protective measures

Common misinterpretation of the overvoltage protection classes

A: Working voltage is what counts. I can measure safely as far as the declared working voltage of my equipment exceeds the measured one.

This statement is completely wrong since it does not assume the presence of overvoltages on power lines.

B: CAT III 440 V phase-phase means a higher protection than CAT III 300 V phase to earth.

Wrong.

Some producers define a higher overvoltage category between phase-phase conductors.

This does not mean a higher protection degree since faults between live (phase, neutral) conductors are treated as less dangerous than faults between live/PE conductors.

The user usually stands on the ground (PE) during a measurement. If a fault to earth happens in the instrument, eventual fault currents could flow through the user's body.

Therefore the IEC 61010-1 standard defines a higher protection degree (double insulation) between live conductors and instrument parts that could be connected to PE. For the same overvoltage category the demanded protective measures between phase/phase, phase/neutral conductors are lower (basic insulation) than for phase/earth conductors (double insulation).

A higher protection of the phase-phase circuit should not be interpreted as an advantage.

For a relevant comparison the phase to earth values must be compared.

C: A higher voltage in the overvoltage protection definition means better protection.

Partly wrong.

Table 1 shows that the test voltage is the same for CAT II 600V and CAT III 300V. Even more, CAT III 300 V must sustain a transient with more energy available (not in the scope of this document)! Both, category and voltage must be considered.

D: Can test equipment of CAT III 300 V (phase to earth) be applied to overhead lines (CAT IV) for 230 V supply?

No.

As defined in the classification of overvoltage category, overhead lines are a CAT IV environment. Using the equipment in an environment with higher overvoltage category than rated, is hazardous live because of possible high overvoltages and much higher fault currents. A measuring instrument declared for at least CAT IV 300 V should be used.

METREL CAT IV installation testers

All latest METREL multifunctional installation testers and accessories are designed according to CAT IV 300 V.

The CAT IV design was proved and confirmed by the independent notified laboratory SIQ.

EurotestEASI

EurotestXE

EurotestAT

EurotestXA



Figure 6: METREL CAT IV installation testers

Metrel

Measuring and Regulation Equipment Manufacturer

Ljubljanska 77

SI-1354 Horjul

Tel.: +386 (0)1 75 58 200

Fax: + 386 (0)1 75 49 226

E-mail: metrel@metrel.si

<http://www.metrel.si>