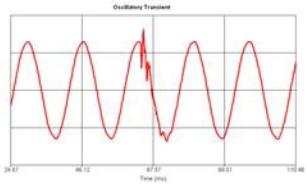
Common PQ Issues: Transients

A transient is defined per IEEE 1159 as a phenomenon or a quantity which varies between two consecutive steady states during a time interval that is short compared to the time scale of interest. A transient can be a unidirectional impulse of either polarity or a damped oscillatory wave with the first peak occurring in either polarity.

Transients are responsible for many power quality related malfunctions and failures. Transients can cause component to fail such as fuses, surge protectors, automatic transfer switches, cable switch gear, CT's and PT's. Transient voltages can result in degradation or immediate dielectric failure in all classes of equipment. High magnitude and fast rise time contribute to insulation breakdown in electrical equipment like switchgears, transformers and motors. Repeated lower magnitude application of transients to equipment can cause slow degradation and eventual insulation failure, decreasing equipment mean time between failures. Transients can cause back up UPS systems to turn on and off excessively. This can reduce the life span of a UPS system.

Generally there are two different types of transient over-voltages: low-frequency transients and high-frequency transients. Low Frequency transients have frequency components in the few-hundred-hertz region and are typically caused by capacitor switching. High-frequency transients have frequency components in the few-hundred-kilohertz region and are typically caused by lightning and inductive loads.



There is also the phenomenon known as extremely fast transients, or EFT's. Extremely fast transients have rise and fall times in the nanosecond region. They can be caused by arcing faults, such as bad brushes in motors. Due to the rapid rise and fall times of extremely fast transients they are rapidly damped out by just a few meters of distribution wiring. Standard line filters, included on almost all electronic equipment, filter out EFT's.

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The limited impact of extremely fast transients can be understood by examining the formula for capacitive reactance.

$$Xc = \frac{1}{2\pi f C}$$

Xc = Capacitive Reactance

f = Frequency

C = Capacitance

If we solve for capacitance in this formula, it can be written as the following.

$$C = \frac{1}{2\pi f Xc}$$

It can now be seen that as the value of the frequency increases, the capacitance decreases. This means that the higher the frequency, the less capacitance is required to pose a low resistance path.

Transients can be responsible for various component failures. These components can include fuses, surge protectors, automatic transfer switches, cables, switchgear, CT's or PT's etc. Transient voltages caused by lightning or switching operations can result in degradation or immediate dielectric failure in all classes of equipment. High magnitudes and fast rise times contribute to insulation breakdown in electrical equipment. Repeated lower magnitude transients can cause slow degradation and eventual insulation failure, decreasing equipment mean time between failures.

Transients can damage insulation because insulation, like that found in wires, has capacitive properties.

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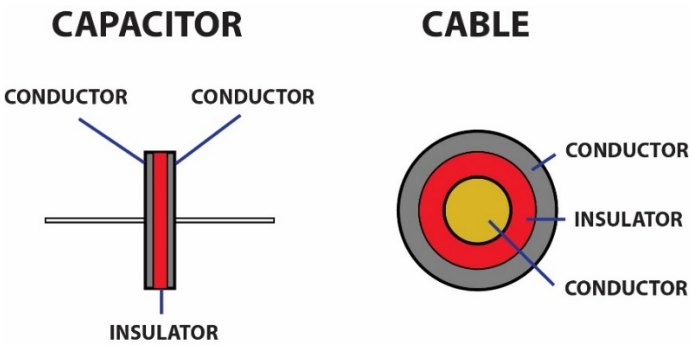
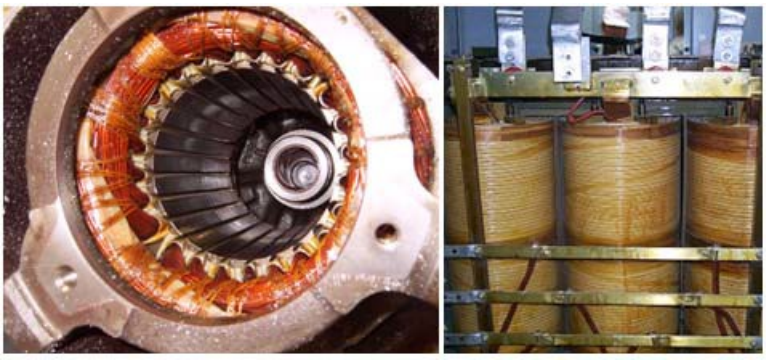


Both capacitors and wires have two conductors separated by an insulator.

If a transient pulse with a high enough frequency reaches a component, the capacitance of that conductor-insulation junction will present a path. If the transient pulse has enough energy it could damage that section of insulation.

Transients can cause the insulation to break down in motors and transformers.



When a transient reaches the coil of a motor or a transformer it will dissipate the majority of its energy in the first few coils. Each successive coil presents more resistance and capacitance to the transient. This will reduce its magnitude and increase its period, reducing the energy. Since the majority of the energy is transferred to the first few coils, this is where the damaged insulation will typically appear.

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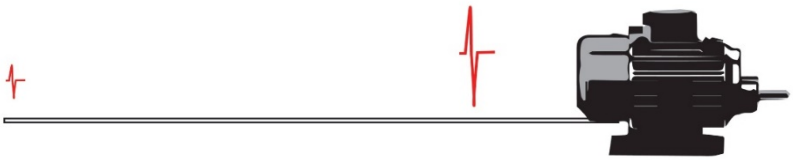
In motors, fast-changing PWM voltage pulses can interact with the distributed inductance and capacitance of motor leads. This can result in an amplified peak voltage at the motor terminals. This peak voltage further stresses and degrades the insulation around the stator winding of the motor. The peak voltage magnitude at the motor terminals depends on the motor lead characteristics and the surge impedance of the motor; the smaller the motor and the longer the leads, the greater the peak voltage. For this reason, it is recommended to avoid long motor leads.



Transient voltages can cause computer equipment to lockup and data to get garbled, or even damage computer equipment. When a transient strikes your computer, it can cause internal noise spikes that may disrupt data. If the transient has sufficient energy, it can cause an arc within the internal components of the computer.

Transients can also affect fluorescent lighting. A fluorescent light illuminates because the gas inside of the light is ionized when voltage is applied across the electrodes. Transients can produce excessive energy that can displace the material within the electrodes. This will eventually reduce the amount of light given off by the fluorescent light and reduce the efficiency of the light. The reduced efficiency will reduce the life of the fluorescent light.

Some of the common causes of transients include lightning, load switching, capacitor switching as well as loose wiring.

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Lightning is the leading cause of power-line disruptions and outages. If facilities are not properly equipped, lightning can cause millions of dollars in damage and downtime of critical equipment. A bolt of lightning can be over 5 miles long, and reach temperatures in excess of 20,000 degrees Celsius. The current-carrying capability of a lightning bolt can be upwards of 90,000A. Lightning can affect distribution equipment, causing the equipment to burn out, catch on fire, or even explode.

Direct lightning strikes or high electromagnetic fields produced by lighting can induce voltage and current transients in electric power lines and signal carrying lines. These will typically be seen as unidirectional transients, either positive or negative.

When an inductive load is turned on or off a transient is produced. Transformers can also produce large transients while energizing. The transient is produced as a result of the collapse of the magnetic field of the coil.

Capacitor banks are switched in and out on circuits to compensate for reactive power caused by inductive loads. When the capacitor bank is switched into the circuit there is an initial inrush of current. The added capacitance causes a phase shift. This will cause a low-frequency transient that will have a characteristic ringing. These types of transients are referred to as oscillatory transients. These types of transients can cause sensitive equipment to trip out and cause UPS backup systems to turn on and off multiple times. This can reduce the life of UPS systems. Since capacitor banks are used to compensate for reactive power caused by large inductive loads, they are switched on and off frequently. This makes oscillatory transients a very common power quality phenomenon.

Common PQ Issues: Transients

Transients are one of the leading causes of equipment malfunctions and failures. Understanding the cause of transients and how they affect various types of equipment will allow companies to improve the quality and reliability of their equipment. Monitoring incoming power by using Power Quality recording devices can help identify potential power quality problems before they cause costly malfunctions.