When Lightning Strikes: How Electrical Devices Are Affected

By Michael Brinker, P.E.

Summer storm season is quickly approaching, and with it a multitude of reported lightning and power-surge damages to electrical devices.

The term "power surge" actually covers several types of disturbances that occur within power lines. These include transient voltage spikes, single phasing, flickering, swells, and sags. The most common disturbance associated with electrical equipment damage is a transient voltage spike, which is a short-term excessive voltage. These spikes typically last less than one complete 60 Hz power cycle (less than 17 milliseconds) and can be caused by direct lightning strikes to equipment, lightning strikes to the electrical grid, indirect lightning strikes, or disruptions in the electrical grid. Other power surge-related disturbances are typically associated with electrical grid issues.

DIRECT AND INDIRECT LIGHTNING STRIKES

A direct lightning strike to a piece of equipment will leave obvious evidence of damage, such as charred or melted components. Direct strikes on most residential and commercial devices are uncommon, especially when equipment is located within a building.

In an effort to mitigate transient voltage spikes from direct strikes to the utility grid, electric utilities incorporate shielding wires and lightning arrestors to route lightning strikes to the ground. While shielding wires and lightning arrestors are effective, they are not able to completely eliminate lightning-related transient voltage spikes through the electrical grid. However, devices are more commonly damaged by transient voltage spikes associated with one of two indirect forms of indirect lightning strikes: inductive coupling or ground potential rise.

Inductive coupling occurs when lightning strikes near long conductors, such as power and telephone lines. The lightning strike creates an electromagnetic field, which induces transient voltage spikes into the conductors. (On a smaller and more controlled application, the wireless charging feature of newer mobile phones relies on inductive coupling.) Devices connected to telephone and internet communication wiring are particularly susceptible to lightning-related inductive coupling voltage and current spikes because the internal components operate at lower voltages and currents than the typical devices connected to electrical wiring. Therefore, induced voltages and currents can exceed the limits of these internal components.

The phenomenon of ground potential rise occurs when a lightning strike creates a localized area of energy in the ground. The material that makes up the ground (soil, water, and rock) is not a perfect conductor, and therefore it impedes the energy from being immediately dispersed throughout the entire earth. This leads to a momentary rise in the potential of the ground in the area of the strike.

The electrical grid is set up such that all equipment is connected to the ground. When a lightning strike causes a localized rise in ground potential, the energy seeks a way to distribute through the entire earth. The energy "back feeds" through the grounding connections at the lightning strike location and is dispersed through the grid to other grounding connections. This back-feeding can create a transient voltage spike in connected devices.

DISTURBANCES IN THE ELECTRICAL GRID

In addition to lightning strikes, storms also bring high winds that can topple trees onto power lines and disrupt the electrical grid. Transient voltage spikes can occur when higher voltage power lines contact lower voltage power lines, or when utilities restore power following an outage.

Single phasing occurs when one of the three phases serving larger electrical equipment is disconnected, which can occur when trees sever power lines. Three-phase electric motors will continue to operate with the loss of a phase, but they draw increased current through the other phases, which can result in overheating.

Short-term outages known as flickering occur when the incoming electrical service suffers multiple short-term interruptions that turn the power on and off repeatedly before settling into its final condition. A common cause of flickering is tree branches making contact with power lines. These rapid on-off-on fluctuations may cause damage to devices such as electric motors that are not designed to withstand these rapid changes.

A short-term increase in voltage over multiple cycles is typically called a swell. If the swell lasts very long, it may cause damage to appliances and electronics. A sag occurs when the amplitude of the normal supply voltage falls below its normal voltage. While sags do not normally damage equipment, they may cause electronic equipment to reset.

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