A Lightning Primer
A tongue in cheek look at why lightning is damaging

Few natural events incorporate as many emotions as a lightning storm. Fear, wonder and awe leading to curiosity bordering on the morbid have inspired mankind to relate to lightning with almost mythical reverence. The effect of a lightning storm on the human psyche was harnessed early on by Hollywood producers, whose extensive use of lightning as a prop to enhance the spine tingling effect of a horror movie reflects just how mythic this natural phenomenon is. It is not surprising then, that much of what the average person knows about lightning is erroneous, and as such, a real lightning storm quite adeptly blitzes Mr. Average's home entertainment center; depriving him of his primordial joy- scaring himself silly watching Hollywood lightning strike in harmony with the antics of a malodorous ghoul.

Lightning causes forest fires, yet no evidence of fire is evident on Mr. Average's home entertainment centre. Lightning never strikes twice in the same place- goes the old adage from the farmer's almanac, yet we are told that the Empire State Building is hit hundreds of times each month. The external area of this great landmark proportional to the many months since it was completed points to the probability that it is being hit in the same spot more than once. No fires have been reported, and I am told that electronic devices have permeated the building over the past decades at an alarming rate, with few complaints regarding loss due to lightning storms. What do the purveyors of electronic devices in the Empire State Building know that Mr. Average does not? Why was Benjamin Franklin so happy at his shocking discovery when lightning hit his metal kite string? Certainly Ben had no problems with his home entertainment center.

Let's start with some relevant facts about lightning. We have all heard of thunderstorms "brewing". Few, however, have seen the recipe for brewing a good thunderstorm. Mother Nature keeps this recipe close to her chest, and has yet to disclose her special lightning recipe. Scientists have produced different recipes for brewing the storm, and like quibbling children at the dinner table can't agree on the best recipe, so we will ignore the actual mechanics and concentrate on the final product. The brewing storm produces a high concentration of positive charge on the earth, and a high concentration of negative charge on the underside of a large cloud. The air between them is a dielectric preventing the negatives from flowing to the positives in a constant and safe manner. If there was a conductor between these two concentrations, the constant flow would never allow a build up of pressure between them.

The high resistance of the air allows the charges to build up pressure until the attraction between them overcomes the resistance of the air, then all hell breaks loose as this tremendous charge breaks through at once, short circuiting the concentration of opposite charges and creating a tremendous flow of charges from one concentration to the other until the pressure equalizes.

For those of you who remember some grade school physics we have a giant capacitor that has flashed through its dielectric. For those of you who don't, there's a good horror movie on channel 3. In any case, we have an electric current flowing through a medium of ionized air. Now back to grade school physics and Ohm's law. The voltage between any two points is proportional to the current flowing through a conductor (a tremendous amount) and the resistance of the conductor (in our case ionized air- not the best). The Energy inherent to a lighting strike is an integral of the current over time. Although a lighting strike lasts no longer than a milli-second, the calculated amount of energy under a good strong lightning strike to earth has been calculated as sufficient to supply the needs of a family of five living in a 200 sq. meter house in the Jerusalem hills during the winter for 16 days.

Now what was Ben Franklin so excited about? Ben and his buddies lived in wood houses. When dielectric pressure builds up, it will flash through at the point of least resistance. Now gaze across an expanse of flat land through the eyes of the leading electron in a brewing, pressurizing capacitor-like cloud ready to burst down to ground through the point of least resistance. As the leading electron, where would you jump to? Pressure will continue to build until it overcomes the resistance of the air between the cloud and the earth. Now if a hill should present itself, lessening the distance and consequently the resistance, you will jump at the opportunity, houses would work too; particularly if the house is wet, as they are wont to be during a storm.

Now the lightning is flowing to ground through the house roof and walls. The water that attracted it boiled away quite quickly, leaving a path of resistance quite high in comparison to the water. Recall our grade school physics from a few paragraphs ago. The current is a given, the amount of charge that has to flow to equalize the pressure between the cloud and earth. The Energy inherent in such a charge was calculated as being quite high. Now that energy is dissipating itself on the walls of the house at a rate directly proportional to the square of the current and the resistance of the walls. Simply put for those of you back from the movie on channel 3, the house burns down; very quickly.

Ben's leap of intellect was that lightning prefers to run down a metal conductor rather than a wood semi-conductor. His ingenious invention was a long metal pole next to the house to attract the lightning to ground in an efficient path. When lightning hits the pole, the resistance is very low, so the current goes to ground very efficiently and quickly. No lighting in its right mind would go to ground through a wet house when it can have a nice metal pole!

So everything was great. Lightning struck, poles got hot, houses stayed wet and people were safe and happy. Now back to channel 3. At some point, Ben's wife chided him for wandering around in a wet coat and forced him to surrender it to her to be hung up and dried (the coat, not Ben). She hung the coat on a metal clothes hanger and placed the clothes hanger on a peg innocently protruding from the wall closest to Ben's new invention. As the family sits snuggly in front of a cozy hearth, lightning strikes; the brilliant flash and simultaneous roar of thunder infer a direct strike. From amidst the heart stopping blood chilling shock of a direct lightning strike, the smell of fire erupts as Bens drying coat bursts into flames! The wood house was spared as the lightning struck the more convenient metal pole, however the high charge and quick rising current created a strong electromagnetic field that induced electric voltage into the coat hanger, which is a closed conductive loop. This high voltage created a high current in the closed metallic loop that heated the wire to the point where it glowed red.

Ben, being a scientific kind of guy must have realized the problems inherent in his new invention. However, I am certain that Ben learned to be prudent in the placement of his lightning rod, and even more so in the placement of all delicate computing devices purchased by him since. However, Ben probably had few problems with his microprocessors, since electricity as a useful form of energy was still waiting to be invented. Lightning going to ground through a lightning rod saved the house from burning and did nothing more than create induced voltage in conductors through out the house. Since most conductors in the house were of heavy gauge, skillets, tankards, bailing wire etc. there were few losses due to this induced voltage. When the conductors began to include electronic circuits, the problem became somewhat more evident. When the Pentium processor went from 3.5 million to 42 million transistors in the same sized chip, the problem became somewhat more acute.

This aspect of the lightning problem is, however, easily solved. By placing the circuits and delicate wiring inside a grounded metal container, the electromagnetic field will be diverted to ground before it is induced into the interior circuitry. The current going to ground, however, creates another electromagnetic field that induces into the container, though much reduced. The obvious answer to this conundrum is to put our grounded metal box inside another grounded metal box.

So we have solved the lighting problem. No houses are burning down, and computers, TVs, CDs and all our other favorite acronyms are safely ensconced in some form of Faraday cage (named for Michael Faraday, who lived after Ben Franklin and still long before he could switch on a light bulb) should the need arise.

So Ben and Michael lived content lives knowing that their delicate electronics where now safe from lightning. And in fact this was so since their houses were void of any electrical conduits connecting their delicates to the city grid system. This was primarily due to the fact that there was no city grid system, or any grid system in fact, since only at the turn of the 20^{th} century would Tom Edison and GE begin connecting houses to an electrical grid system on the east coast of the US.

When Ben and Michaels' house were finally connected to a city grid system, things really started heating up. To take advantage of electrical power distributed in a city grid, Ben and Michael had to create an electrical distribution system in their house consisting of two wires carrying potential (voltage) between them and a third wire connected to the ground, for safety reasons. For similar reasons, one of the two voltage wires is also connected to the ground at the electric panel. So the operating voltage of all sockets in the house, and the panel from whence they originate is between the "high" side delivered by the city and the ground. We now have another physical phenomenon that contrives to turn our beloved electronic devices into toast. To understand this effect we have to return to Ohm's law. Ohm's law relates equality between voltage on one side and the product of current and resistance on the other.

Now, lightning strikes the house and goes to ground through Ben's efficient invention, the current is in the high tens of thousands of amperes, the resistance is quite low, probably a couple of Ohms. The voltage drop on this current path is equal to the tens of thousands of amperes multiplied by the couple of Ohms of resistance; that makes for tens of thousands of volts, between the house ground and- what? That is the hard part to visualize. The voltage is between the house ground and the wires coming into the house from the city grid system, which is grounded on the city's side. So we have tens of thousands of volts between the ground bar in the electric panel (that is connected to one of the house "power" wires), and the wires coming in from the city grid system. That means that the plug in the wall connecting our delicate electronic device to the grid is now supplying substantially more than 230V! The energy inherent in this over-voltage phenomenon is 25 times greater than that inherent in the over-voltage due to the induction phenomenon that set Ben's coat aflame.

So you ask, what are Ben and Michael to do? We see that we have two separate phenomena occurring during a lightning strike, induction and potential difference between the city grid ground and the house ground. The induction problem exists even when the lighting strike is not into the house. It has been calculated that a powerful strike a distance of one hundred meters away produces two thousand volts in every meter of wire in the house. The answer lies in equalizing the potential by taking the potential to earth as current in a controlled manner at some spot away from our delicate machinery and electronics. This is accomplished by mounting a surge protection device between each supply wire and the ground wire. During normal voltage situations, these devices are of high resistance, not allowing any current to flow between the wires and the ground. When the voltage rises above a set value, these devices begin to lower resistance, until they are short circuiting the wires to ground. When voltage returns to normal, they increase resistance once more.

Large devices are installed in the electric panels, where the foreign city grid ground enters, and smaller devices are installed on the entrance to any appliance or computer that we wish to protect from induced voltages. A variety of technologies exist that are harnessed by producers of surge protection devices. Technologies of varying capabilities for shunting surge energy to ground have different effects on the electrical system as a whole and must be taken into account during the selection process.

It is important to understand that lightning is not the only source of damaging over-voltages. Switching any appliance on or off creates an over-voltage as the zero resistance of the switch contacts break, creating an instance of high yet not high-enough resistance. Switching over-voltage is often the culprit when incandescent light bulbs burn out frequently despite frequent terminal tightening. Air conditioner compressors cycling on and off accelerate the wear and tear on all other electrical appliances in the installation. Home owners bordering industrial areas will find that their appliances and electronics are replaced more frequently than their friends living farther away. The electrical utility switches capacitor banks on the grid to stabilize reactive loads that can deliver a spike deep into the residential electrical system. A power outage creates powerful surges both on the power cut and when the power returns.

Surge protection is not only for lightning events. All installations require surge protection at least on the sockets feeding expensive or important electrical devices. It is important to ensure that the protected sockets are used only for the protected device. I have seen a plumber plug a high powered hand drill into the socket adjoining that of a kitchen microwave. At the end of the day, the microwave had burnt out; the drill was fine, and the plumber, quite convinced that he understands electricity, claiming emphatically that it is impossible for his drill to have caused the damage.

We now understand the basic mechanics of damage due to lightning and over voltage. In Israel, where the use of a lightning rod is very rare, damage to buildings due to lightning is non the less very rare due to the prevalent construction method of reinforced concrete columns supporting cinder block walls. So while you are shivering away in an Israeli built cave watching the mould grow in the corners due to the ignorance of things insular and the concept of a vapor barrier, take solace in the fact that you are safe from lightning induced fire.

Lightning damage in Israel is almost totally due to over voltage induced by the lightning strike; a direct strike that causes raised potential of the ground or a nearby strike that induces voltage into all conducting elements. Damage due to lightning, however, takes a back seat to damage due to switching events. With this useful statistic, it can be deduced that the primary concern should be to invest in protection that will deal with switching as readily if not more so than lightning.

In situations were damage due to lightning is a real concern; an expert in lightning protection should be contacted. If the interest in lightning protection is induced by the attitude of "an ounce of prevention", then the focus should be on protecting primarily from switching events, since any switching surge suppressor will also deal with a certain level of lightning over voltage.

For consultations of any kind, please feel free to contact me at: mike@lightning.co.il