circuit operation for the safe strike ESE

how lightning forms

A **cloud-to-ground lightning strike** starts as a channel of negative charges makes its path towards the ground. This occurrence is known as a stepped leader. The stepped leader continues towards the ground in a series of steps that are each about 50 to 100 metres in length. This stepped leader can branch out in many directions.

In response to the discharge of negative charges coming from the cloud base, currents of positive charges start moving upward from the ground, usually along elevated objects; these are called streamers or upward leaders. There is an associated rise in electric field at ground level and especially around tall and sharp objects such as tress.

When the stepped leader and the upward leader meet, usually between 30 to 100 metres above the ground, the negative charges begin to flow downward. Almost instantaneously, a much larger and luminous electric current shoots up to the cloud, following the path taken by the stepped leader. This is known as the return stroke, and it is also what we see in the sky that is known as lightning. This whole process occurs so quickly (200-250 microseconds) that the lightning appears to travel from the cloud to the ground, when in fact, the opposite is true.

how SAFE STRIKE works

circuit operation

please note: for commercial confidence we have given working examples only for transformer windings and their ratios, voltage and capacitor values.

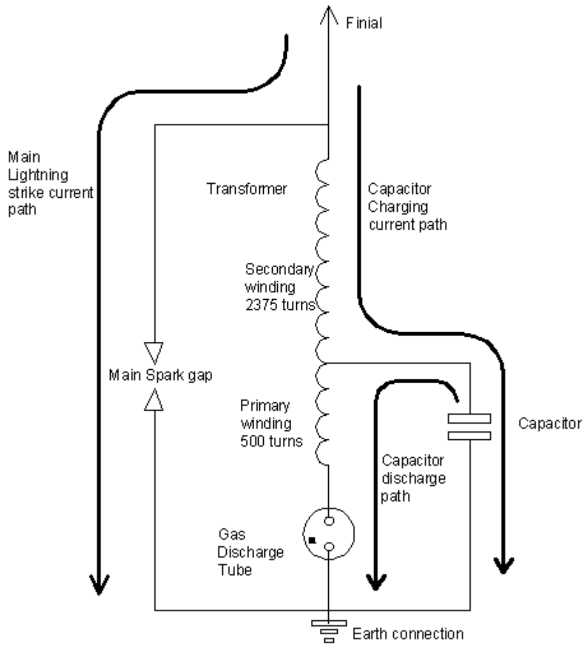
The circuit is based on ‘energy storage’ and a controlled point on when this energy is released.

Firstly, the energy storage component is the capacitor. Three capacitors are actually used in the circuit but they are connected together in a parallel configuration to form one capacitor which has 3 times the capacitance value. So if each capacitor has a value of 220pf (pico farads) the equivalent single capacitor will be 660pf.
For simplicity the rest of the circuit operation will refer to a single capacitor.

Capacitors are normally charged from a voltage source (a power supply) and take a time to ‘charge up’. This time is dependant on the power supplies ability to supply not only voltage but current.
The more current, the faster the capacitor will charge. Once charged, capacitors have the ability to remain charged even if the power supply is disconnected.
The amount of energy ‘stored’ in the capacitor is related to the size (its value) and the value of voltage it is charged to. This energy is measured in Joules.

The method of charging in this application is created by the lightning phenomenon. Charging takes place due to the electrostatic ‘charge in the air’. Just like rubbing a balloon on a jumper, a static charge exists on the balloon which has a large voltage but a very small amount of energy.

When a ground discharge is imminent, the atmospheric electric field on the ground rises to 15-20 KV/m.
As this build up occurs, the capacitor in the circuit is charged with a very small current.
All electrical circuits involve the flow of current and for current to ‘flow’ there must be a difference in voltage levels between two points in the circuit.



The diagram shows the capacitor charging path which is from the high voltage area of the finial and through the secondary of the transformer then through the capacitor and eventually to earth.

The current path though the transformer secondary is very small and does not cause any ‘activity’ associated with the transformer.

At the moment this path just provides the very small charging current to the capacitor.

Sometimes a ‘water analogy’ is used to describe this type of circuit. Capacitors are tanks which are filled with water from a small pipe – the water flowing in the pipe in this case is the capacitor charge current .
This is a good analogy as you can visualise the capacitor - water tank’s level rising.

This charging current, which is totally dependant on the electrostatic conditions, gradually increases the voltage on the capacitor. This voltage is connected, through the transformer primary winding, to the ‘active’ side of the gas discharge tube.

The gas discharge tube (GDT) can be regarded as a voltage controlled switch which is completely open circuit until it is ‘triggered’.

The voltage rating of the GDT defines its triggering or switching point. The circuit uses a 1500 Volt type so when the voltage on the capacitor reaches this point, the GDT triggers and connects the transformers primary winding to earth.

Using the water analogy again, this is the point that the water tank tips over and all of the water which has been collected over a long period of time is suddenly released.

At this point all the energy from the capacitor is transferred into the primary winding, shown as the capacitor discharge current.

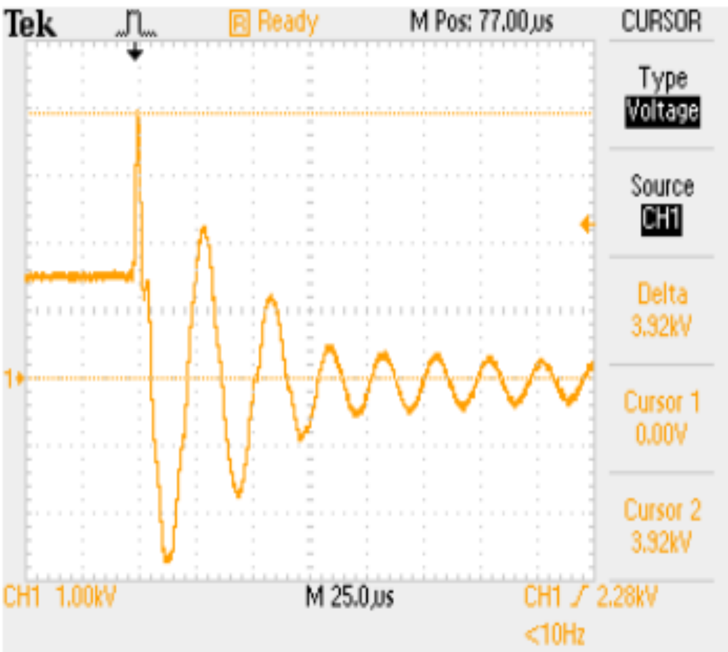
At this crucial stage the sudden energy transfer also places the whole of the 1500 volts across the primary winding of 500 turns. The sudden increase in magnetic field and the number of turns in each section of the transformer perform a ‘stepping up’ of voltage due to the large amount of turns on the secondary winding.

This voltage is stepped up by the same winding ratio eg 500:2375 is equivalent to 1:4.75.

So the initial 1500 volts is stepped up to 1500 x 4.75 = 7125 volts.

This high voltage appears on the transformers secondary winding for a short time, which of course is connected to the finial. It is this high voltage that will instigate a single point of upward discharge for a lightning strike. The upward leader is formed earlier than in nature and propagates continuously upwards along the already inonised path of the downward leader to create a meeting point - a lightning strike.

The oscilloscope pattern shows a time line (horizontal) of voltage representing the triggering action while the vertical scale is 1000 volts for each of the ‘squares’



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Starting at the left hand side, a level trace is 1.5 squares above the reference marker ‘1’. This represents 1500 volts. This is the voltage across the capacitor.

At the point of the GTD triggering, there is a very short positive (upward) pulse.

This is where most of the capacitors energy has been transferred to the transformers primary. This action has created a magnetic field in the transformers iron core. This magnetic field can not be sustained because the capacitor has only a limited amount of energy.

The magnetic field has to collapse, and when this magnetic field collapses it will generate a voltage in its own windings – but in the opposite direction. This causes the large negative voltage shown above.

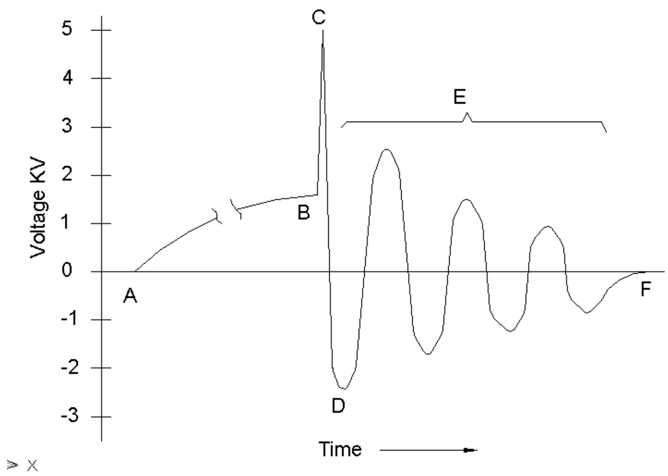
The voltage then slowly oscillates and reduces in size until all of the energy is dissipated.

This oscillation is normal to all circuits of this nature where energy is passed from the capacitor to the transformer – then transformer back to the capacitor….. the cycle repeats until all energy is lost.

The whole cycle will repeat when the capacitor is charged back up to about 1500 volts.

3circuit summary

For completeness the diagram shows the circuit operation and its key stages.



A – Start of capacitor charging (time A to B is unknown and depends on electrostatic charge)

B- The capacitor has reached the threshold voltage of the gas discharge tube (GDT) and the GDT has triggered (acting like a closed switch).

C – All of the capacitors voltage is now quickly connected across the transformers primary winding. A fast positive high voltage is produced by the transformers ratio of windings (1:4.75).

D – The collapse of the transformers magnetic field creates the large negative voltage.

E- Energy is passed to and from the capacitor and transformer (this is sometimes call ‘ringing’) until all energy is used.

F – Circuit at rest

All voltages shown above are present on the finial.