



**samlexamerica<sup>®</sup>**

**GROUNDING SYSTEM  
AND LIGHTNING /  
GROUND FAULT  
PROTECTION**

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## INFO

The information given is intended to provide basic grounding techniques and lightning protection. It is not intended to be a complete course on grounding or a guarantee against protection during a lightning strike situation. Please follow the National Electric Code (NEC) or the local Electrical Code for the required grounding techniques for your electrical system.

### 1.0 LIGHTNING / GROUND FAULT

**Lightning:** is a momentary atmospheric discharge of tens to hundreds of thousands of Amperes of electrical energy through the objects to ground or on to other objects in parallel paths to ground into the ground.

**Ground Fault:** is a condition when a very high voltage, ungrounded current carrying conductor e.g. the Hot / Line / Live conductor of a Power System (transmission line voltage can go up to 500 KV or 500, 000V) touches the Earth Ground due to a fault in the system.

Thus, large amounts of current can also be injected into the Earth Ground when, for example, high voltage lines from sub-stations or transmission towers develop fault to Earth. These fault currents will also create conditions similar to a lightning strike.

*As the value of the discharge current is in hundreds of thousands of Amperes, even very low impedances (consisting of resistances and inductances) in the direct discharge current paths along the soil / other conductors can produce very high voltages that can damage electrical equipment connected or referenced to these conductive paths.*

Damage can also be caused to the electrical systems in the vicinity of the strike by momentary, very high voltage transients lasting for a few microseconds that are developed in conductive parts of the system which are exposed to the intense magnetic fields produced by the flow of hundreds of thousands of Amperes of current in the direct discharge paths. For example, a peak current of around 18, 000 Amperes can flow in a conductor, say the lightning conductor, in a very short period of 20  $\mu$ s at an extremely high rate of change of current ( $di / dt$ ) of around 2000 A per  $\mu$ s (refer to the current pulse wave in Fig. 1). This high rate of change of current will produce very high momentary magnetic field around the this conductor and conductors in the vicinity like solar array cables, battery cables, data cables, power cables, metal chassis of equipment etc. will produce dangerously high induced transient voltages that will damage the associated electrical and electronic components.

### 2.0 GROUND POTENTIAL RISE (GPR)

When the large amount of lightning energy or ground fault current is rapidly deposited into the Earth Ground by a Cloud-to-Ground Lightning

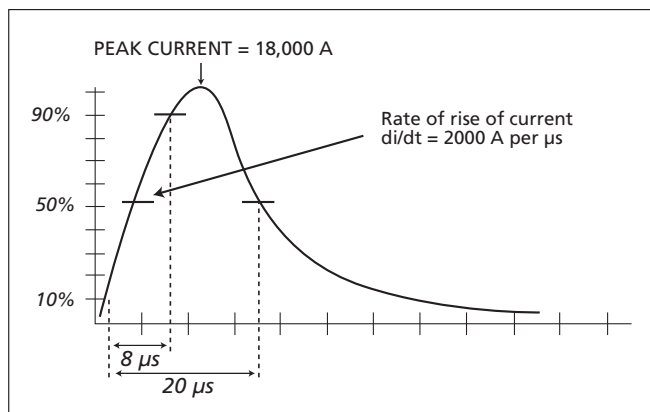


Fig. 1: "IEEE 8 / 20 Model" of lightning current pulse used for specifying lightning protection devices

Strike or by an electrical ground fault on a utility power system, the ground potential at this injection point rises to a higher level with respect to the more distant ground. This rise of voltage along the earth ground path is called Ground Potential Rise (GPR)

For purposes of understanding lightning behavior, it's analysis and for specifying lightning protection devices, a common model of the lightning pulse has been specified by the Institute of Electrical and Electronics Engineers (IEEE). This model of the pulse is called the "The IEEE 8 / 20 Model" and is commonly used in specifying lightning protection devices. Figure 1 shows the current versus time graph of the pulse. It is generally thought that this model is equal to or greater than 50% of lightning events. But, it should be remembered that the other half are more powerful than this model predicts!

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The pulse has a peak value of 18,000A. The current rises from 10% to 90% of the peak value in 8  $\mu$ s at rate of change  $di / dt$  of 2000A per  $\mu$ s. The time taken to rise from 10% to the peak and drop to 50% of the peak is 20 $\mu$ s – hence the name 8 / 20.

In an appropriately grounded system, the high lightning discharge current pulse is channeled through the lightning arrester conductor to the Grounding Electrode and from there, the current is dissipated radially along the surface of the earth around the Grounding Electrode (GE).

When current passes through a DC resistance, it creates a voltage drop along the path. Similarly, rapidly changing current wave front flowing through the inductances of the metal conductor of the lightning arrester / Grounding Electrode (GE) and the metal pipes, rods, wires etc. embedded in the earth ground generate a voltage source that is proportional to the rate of change of current.

Mathematically, the net voltage generated is a sum of the resistive and the inductive voltages as given in Equation (1) below:

$$V = IR + L di / dt \dots \dots \dots \text{Equation (1)}$$

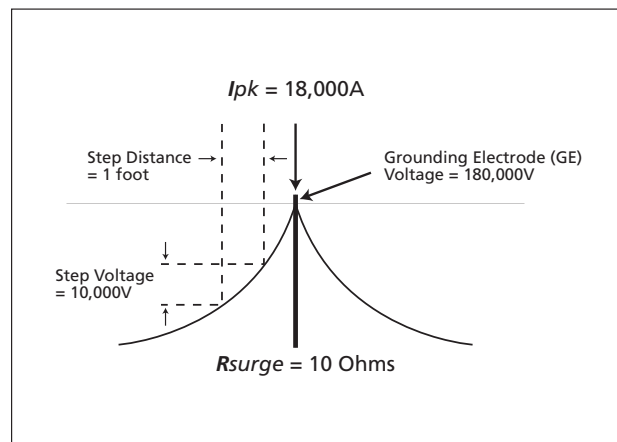
Where,

- V = Voltage in volts, V
- I = Maximum current of the discharge pulse in Amperes, A
- R = DC resistance in Ohms ( $\Omega$ )
- L = Inductance in Henry, H
- i = Instantaneous current in Amps, A
- $di / dt$  = Rate of rise of current wave front of the discharge pulse

### 3.0 STEP VOLTAGE

The current from the lightning pulse / ground fault spreads radially outwards from the point of entry into the earth. As it travels through the mass of the earth, it generates voltage that is proportional to the resistance of the earth mass. Earth is not a perfect conductor – it has resistance and may be considered as infinitely large resistor. The resistance of the earth mass depends upon various factors like depth; temperature; composition of soil e.g. minerals, salts and water content; and embedded conductors like re-bars, pipe lines, cables, etc. The resistance increases with decrease in temperature. Therefore, the Grounding Electrode (GE) should be below the local frost line to minimize this undesirable temperature effect. Generally, the electrode is 8 ft. deep.

Additional induced voltages may be developed in the inductances of the metal conductors embedded in the earth due to the rapidly changing current wave front. Equation (1) above gives the mathematical value of this voltage.



**Fig. 2: High voltage distribution along the Earth Ground from the point of lightning strike / ground fault**

Maximum voltage is developed at the point of entry and this voltage decreases exponentially along the surface of the earth as one moves away. Refer to Figure 2 above where voltage distribution is shown around a single Grounding Electrode (GE) in the presence of an 18,000A lightning strike. A typical Grounding Electrode (GE) should have a resistance less than 25 Ohm but when large amounts of current are dumped into the soil, the area will become less resistive to say 10 Ohm. At a peak current of 18,000A and surge resistance of 10 Ohm, the top of the rod will rise to 180,000 volts and the charge distribution into the ground will cause a step potential that decays as it moves radially from the ground rod. This nonlinear charge distribution will cause the ground surface to develop a voltage gradient that also extends outward radially. Figure 2 shows that a few feet away from the electrode, the voltage gradient is 10,000 volts per foot. Hence, if a person was standing on the ground with his feet 1 foot apart, he will be electrocuted with 10,000V electric shock. Similarly, if two electrical devices were grounded separately a few feet apart, the device that is down stream will be fed with a very high differential voltage and will be fried. Hence, it is important that all the devices should be grounded at a single point as explained below.

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### 4.0 SINGLE POINT GROUNDING SYSTEM

It is important to ensure that ground potential differences are not derived across equipment within a facility during ground potential rises (GPR). One way to ensure this is to adopt a single point approach to grounding of the equipment and services in the facility. This usually entails referencing all equipment grounds in the facility like the generator chassis ground, inverter chassis ground, solar panel chassis ground and the battery Negative ground to a single ground bar (or a number of ground bars that are solidly electrically bonded together), and ensuring that this internal bonded system is connected to the external ground system. "Single point grounding" refers to the single connection between the internal facility ground system and the external ground network. The external ground network can utilize multiple grounding elements such as ground rods and / or counterpoises.

This ensures that there is no voltage potential between chassis grounds of all the devices in the system. No voltage means no current flow through the system and hence, damage will be prevented.

Please see the NEC Code for specific information on grounding requirements, and hardware.

In severe conditions, the generator frame should physically be isolated from the earth by a wood frame or some other insulating means. This assures that the single point ground system is maintained.

All equipment involved in a system should physically be located as close as possible to one another. This reduces the potential that is developed between the ground site and the individual components of the system during a lightning strike. This single point grounding greatly reduces the potential for lightning damage to electrical equipment.



#### **WARNING!**

**If it is not possible to achieve single-point grounding due to large distances between equipment or other variables, other means of lightning protection must be considered. Consult a reputable lightning protection company.**

For more information:  
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