



13101 Camino Del Norte NE
Albuquerque, NM 87123-1602
Tel : 505-298-5400
Cel : 505-301-1100
Fax : 505-293-1111
Email: rlknight@gwestoffice.net
Web Site: RLK&Affiliates.com

RLK & Affiliates

*“Telecommunication
Protection Experts”*

Richard Knight

Lightning Arrester White Paper

This is a White Paper relating to the use of a Lightning Arrester associated with an installation of High Voltage Protection (HVP) Equipment, commonly called a HVI location

While this text may discuss the deployment at a power substation, this type of deployment would also be appropriate for any site subjected to a Ground Potential Rise (GPR). This would include a 911 PSAP center and cell sites. Cell sites would be included because they are exposed to lightning caused GPR and electrical supply caused GPR when associated with a Transmission structure or electric supply substation.

When properly installed in close proximity to the end of a Dedicated cable at a site subjected to a potential GPR and correctly wired to a grid ground dissipating point, a lightning arrester will provide the critical energy dissipating connection for the substation end of a dedicated cable.

Rationale for Lightning Arrester Deployment

The dedicated cable serving a substation is to be grounded at the 300 Volt point, but is to be floating from ground at the HVI location on the substation or cell site ground grid. Therefore, it is supposed to be floating from ground at all points in between the 300 Volt point and the HVP location on the grid.

Because of this fact, the cable shield of the dedicated cable cannot drain energy off since one end is effectively open from contact with the earth.

By connecting a lightning arrester to the cable shield at the entrance to the HVI, the cable shield could have a ground connection under certain circumstances. Those circumstances might be one of the following:

1. The induction of sufficient voltage into the cable from a paralleling conductor that is energized by a lightning strike will cause the arrester to operate and connect the cable shield to the grid ground. Usually this will result in circuit(s) interruption, but the circuit(s) will restore with no consequential equipment damage on the circuit isolation cards.
2. A direct strike to the dedicated or general use cable might energize the cable shield to a sufficiently high level to cause the lightning arrester to operate. However, the cable will probably experience sufficient damage to be inoperable after this event.
3. If the GPR of the site is sufficiently high enough and the fault duration is long enough, (i.e., greater than say 20 or 40 cycles or even more of the inducing power system) then the arrester may operate and connect the grid to the cable shield. If the fault does not clear in a reasonable time, say 40 cycles or more, cable damage may occur. The severity of this damage would be determined by the actual time duration and energy level of the GPR event.



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The use of the lightning arrester on the dedicated cable shield in proximity to the HVP equipment provides a path to the substation ground for the induced energy.

The following related questions surface:

- A. How does the energy get onto the Dedicated cable shield?
- B. How does the energy get onto the Dedicated cable pairs?
- C. How do the Lightning Arrester and the Dedicated cable shield help with the induced energy on the cable pairs?

The answers to these salient questions are presented below:

A. How does the energy get onto the Dedicated cable shield?

The faulting power line, or for that matter any paralleling conductor to the Dedicated cable, has an energy flow as a result of a lightning strike or power conductor drop or slap to adjacent conductor(s). This energy flow is then induced into any paralleling conductor. In this case a telephone cable shield (in most cases the Dedicated cable shield).

While the General use cable may also become energized, the normal grounds placed upon the General use cable at defined intervals will greatly reduce any impact from this event to energize the Dedicated cable.

Usually, the only way the Dedicated cable is impacted is when this event occurs in that geographical location that is within the Zone of Influence (ZOI) of the electric supply location being protected.

B. How does the energy get onto the cable pairs?

The faulting power line (or for that matter any paralleling conductor to the Dedicated cable) has an energy flow as a result of a lightning strike or power conductor drop or slap to adjacent conductor(s).

This energy flow is then induced into any paralleling conductor--in this case telephone cable pairs (in most cases the Dedicated cable pairs). While the General use cable may also be involved, the normal grounds placed upon the General use cable at defined intervals will greatly reduce any impact from this event to energize the Dedicated cable pairs.

Usually the only way the Dedicated cable pairs are impacted, is because this event occurs in that geographical area that is within the Zone of Influence.

All this induced energy arrives at the substation end of the dedicated cable with nowhere to go to drain off to ground. Therefore, It can and usually does do damage to the circuit cards and the HVP shelf located at a HVI installation.



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C. How do the Lightning Arrester and Dedicated cable shield help with the induced energy on the cable pairs?

Without a connection to ground at the substation end of the Dedicated cable the shield has no function in assisting in the reduction of the induction in the above two scenarios.

There is a path for this energy to flow if:

1. The arrester properly connected to the end of the dedicated cable shield at the substation
2. The arrester is connected with the correct size and length of wire,
3. The tail of the arrester connected to the grid ground with the correct size and length wire, and with the correct size and length of wire from the HVI ground bar (if utilized) to an earth dissipating point on the substation grounding grid,

If the amount of energy on the dedicated cable shield elevates to a potential high enough for the arrester to operate, the shield of the dedicated cable, through the arrester, now has a path to ground. This connection to ground along with the connection to ground of the dedicated cable back at the 300 volt point will now allow current to flow on the dedicated cable shield.

This current flow is in the same direction as the current flowing on the cable pairs. Because of the shields' close proximity to the cable pairs it will induce into the cable pairs at the same time that the induction into the shield is occurring. However, this induction into the pairs from the shield is at a 180° phase angle to the energy flowing on the pairs from the originating parallel induction source.

This opposing energy flow (counter Electro Motive Force (EMF)) then reduces (effectively neutralizes to a degree) the combined induced energy on the cable pairs. The end result will be a lower energy value being presented to the circuit cards and the shelf at the substation end.

Without the arrester to create the grounding path on the cable shield for the counter EMF to appear onto the cable pairs, the end impact will be equipment damage, in some cases severe.

See Figure 1 below for a diagram of the ZOI (Zone of Influence), the 300 Volt Point contour, the Telephone Co.'s pedestal, the General use cable, the Dedicated cable, and the HVI location on the Ground Grid.



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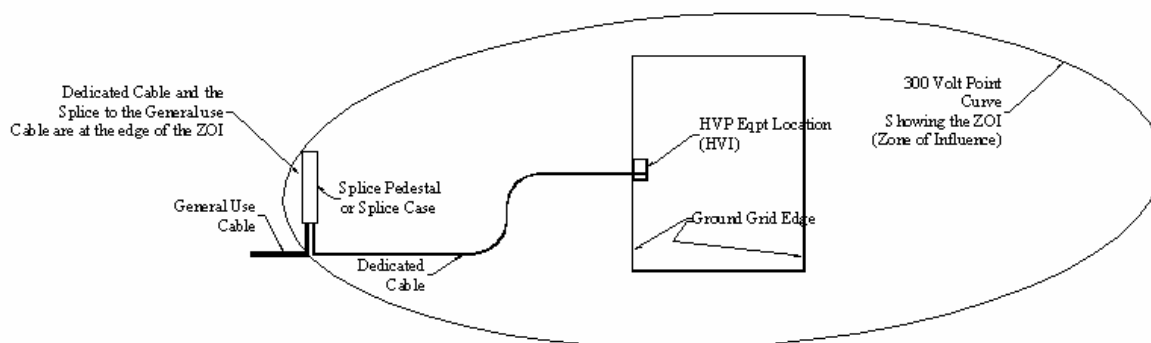


Figure 1

Arrester Deployment Instructions:

The attachment of the top of the arrester to the cable shield should be done with a conductor length of 1 foot or less of #6 AWG copper ground wire. This connection must end up with the direction of the ground wire to be in the same direction as that of the cable shield. This allows an easy transition of the energy off of the cable shield flowing at a high rate to transfer onto the ground wire and be routed to the arrester with few if any bends. **DO NOT** use a 180° bend as is often done on a cable shield in splice closures. See Figure 2 below for a graphical representation of the only acceptable ground wire routing off of the cable shield.

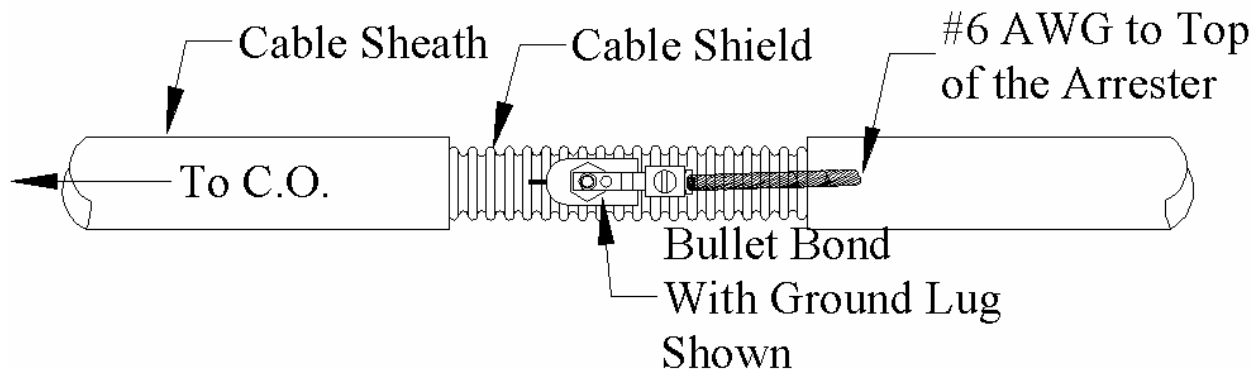


Figure 2

The cable sheath and shield on the right hand side of this drawing as shown in Figure 2 may not actually extend beyond the cable shield attachment. The normal vinyl taping over the bullet bond and ground lug has not been pictured here to allow for a clear view of the bullet bond to cable shield connection.

The attachment of the bottom of the arrester to an earth dissipating point on the ground grid should use a conductor that is as short as possible; in fact this conductor length should be 6 feet or less of



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#6 AWG copper ground wire if a HVI assembly with a ground bar has been utilized at the site. That is 6 feet from the HVI ground bar to an earth dissipating point.

Explanation: The length of the ground wire from the cable shield through the arrester to the grid dissipating point must be short. The reason for that is the impact of the inductive impedance of a conductor at lightning energy frequency on the performance of the arrester.

Since lightning is comprised of very high frequency energy (i.e., 400,000Hz) each conductor foot of ground wire adds 1.5kV of value to the operating voltage value of the arrester/wiring configuration. Therefore if a 15kV arrester is used and 8 total feet of ground wire from the cable shield to the grid dissipating point is used, the end result is an operating voltage equivalent of $15\text{kV} + (8 \times 1.5\text{kV}) = 27\text{kV}$ total. That means that the cable shield would have to elevate to 27kV before the arrester will operate and connect to ground.

Don't forget that each additional foot of ground wire will add another 1.5kV to that operating voltage.

Figure 3, below, shows a graphical representation of a proper bond to the shield, a possible all dielectric splice case, and the arrester grounding to the grid. If isolation jacks are used in lieu of a non-metallic splice case for the Dedicated cable to shelf stub connectivity, the arrester attachment to the shield would physically connect onto the cable shield in the High Voltage area of the High Voltage Interface. This would be very near the isolation jacks, but physically on the CO side of the attachment of the cable pairs to the jacks.

The intent is for the sheath of the cable to be intact up to a location in very close proximity (3 inches or less) to the isolation jack wiring area. This will insure that the cable pairs experience an absolute minimum exposure, thereby reducing any possible physical contact with these pairs to a minimum.

It is important to note that Figure 3 specifies a 6 foot maximum ground conductor length from the arrester to a grid dissipating point, whereas the above paragraph says 6 feet from the ground bar. The intent is to make sure that the tail of the arrester is connected to a grid dissipating point at a total wiring distance of no greater than 7 feet.

In addition the radii of the bends in this grounding wire should be a 6" radius (with an absolute minimum of a radius of 4").

Note: The physical arrangement of vertical versus horizontal for equipment orientation is totally dependent upon the site space requirements.



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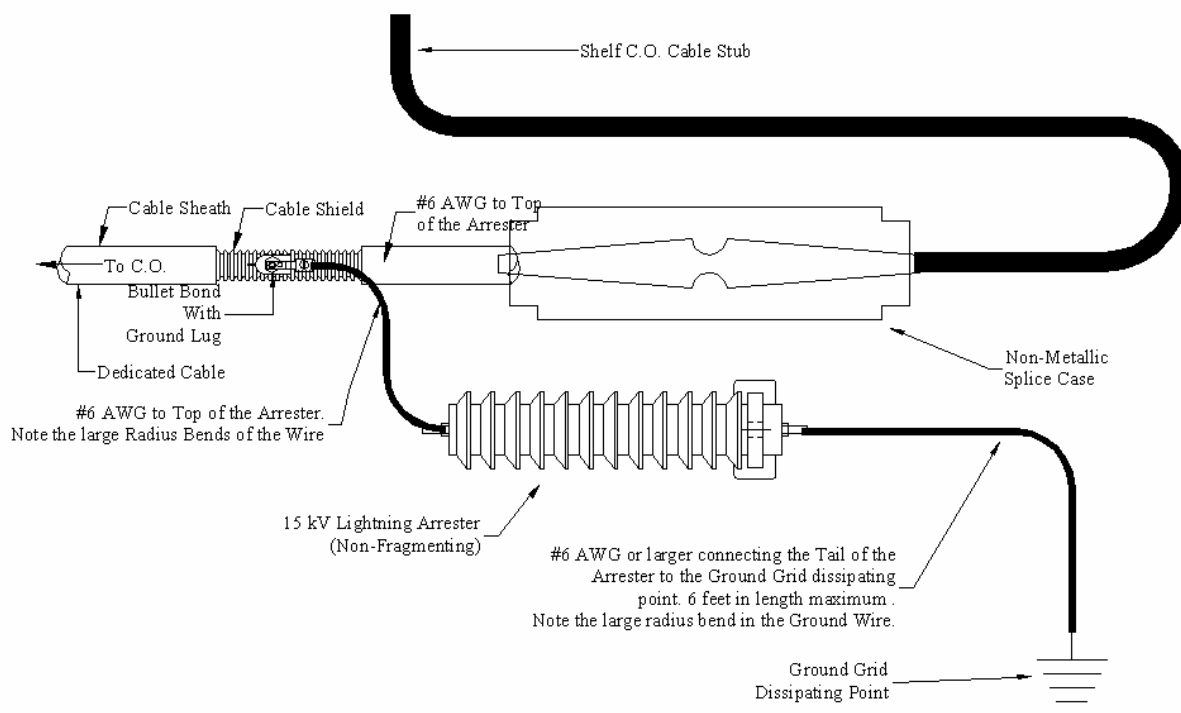


Figure 3

In addition all ground wire bends should be of a 6 inch radius with an absolute minimum of a 4 inch radius. This large radius bend is necessary in order for this conductor to handle the high energy presented to this ground wire from the arrester and then route it to a grid ground conductor at an earth dissipating point. Since this is very high frequency energy (i.e., 400,000Hz) it does not like to go around sharp bends at all. It will choke and not continue or come off of the conductor and find its own path to something to dissipate against.

If a HVI (cabinet or backboard) assembly is in use, the HVI manual states a 6 foot maximum ground wire length. That is the length of the ground wire from the HVI ground bar associated with the HVI assembly to a grid ground dissipating point.

Attaching to a ground wire in a raceway or in an under floor tunnel is **NOT** a grid dissipating point. That is because the wire at that location can not dissipate energy into the earth, it is simply a connecting point.

Lengthening the ground grid connecting wire serving the lightning arrester beyond 6-feet markedly reduces the efficacy of the lightning arrester and increases the probability of circuit service disruptions and equipment damage from lightning strikes in the vicinity of the dedicated cable.

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