Utility System Lightning Protection

Many power quality problems stem from lightning. Not only can the high-voltage impulses damage load equipment, but the temporary fault that follows a lightning strike to the line causes voltage sags and interruptions.

3.3.1 Shielding

One of the strategies open to utilities for lines that are particularly susceptible to lightning strikes is to shield the line by installing a grounded neutral wire over the phase wires. This will intercept most lightning strokes before they strike the phase wires.

Shielding overhead utility lines is common at transmission voltage levels and in substations, but is not common on distribution lines because of the added cost of taller poles and the lower benefit due to lower flashover levels of the lines. On distribution circuits, the grounded neutral wire is typically installed underneath the phase conductors to facilitate the connection of line-to-neutral connected equipment such as transformers and capacitors.

Shielding is not quite as simple as adding a wire and grounding it every few poles. When lightning strikes the shield wire, the voltages at the top of the pole will still be extremely high and could cause backflashovers to the line. This will result in a temporary fault. To minimize this possibility, the path of the ground lead down the pole must be carefully chosen to maintain adequate clearance with the phase conductors. Also, the grounding resistance plays an important role in the magnitude of the voltage and must be maintained as low as possible.

However, when it becomes obvious that a particular section of feeder is being struck frequently, it may be justifiable to retrofit that section with a shield wire to reduce the number of transient faults and to maintain a higher level of power quality. Figure 3.24 illustrates this concept. It is not uncommon for a few spans near the substation to be shielded. The substation is generally shielded anyway, and this helps prevent high-current faults close to the substation that can damage the substation transformer and breakers.

It is also common near substations for distribution lines to be under built on transmission or sub-transmission structures. Since the transmission is shielded, this provides shielding for the distribution as well, provided adequate clearance can be maintained for the ground lead.

Another section of the feeder may crest a ridge giving it unusual exposure to lightning. Shielding in that area may be an effective way of reducing lightning-induced faults. Poles in the affected section may have to be extended to accommodate the shield wire and considerable effort put into improving the grounds. This increases the cost of this solution. It is possible that line arresters would be a more economical and effective option for many applications.

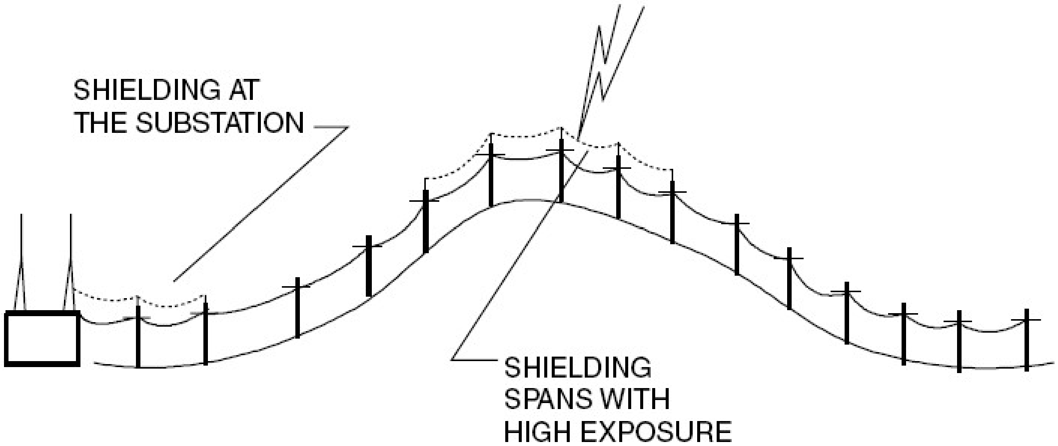

Figure 3.24 Shielding a portion of a distribution feeder to reduce the incidence of temporary lightning-induced faults.

3.3.2 Line Arresters

Another strategy for lines that are struck frequently is to apply arresters periodically along the phase wires. Normally, lines flash over first at the pole insulators. Therefore, preventing insulator flashover will reduce the interruption and sag rate significantly. Neither shielding nor line arresters will prevent all flashovers from lightning. The aim is to significantly reduce flashovers in particular trouble spots.

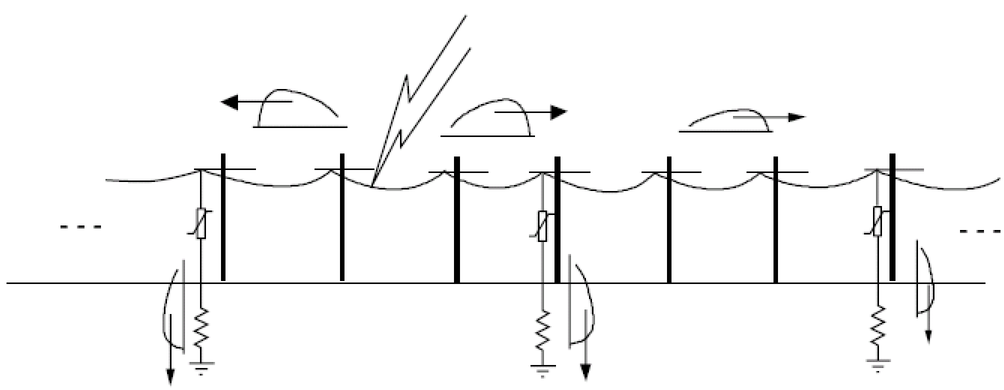

Figure 3.25 Periodically spaced line arresters help prevent flashovers

In Fig.3.25, the arresters bleed off some of the stroke current as it passes along the line. The amount that an individual arrester bleeds off will depend on the grounding resistance. The idea is to space the arresters sufficiently close to prevent the voltage at unprotected poles in the middle from exceeding the basic impulse level (BIL) of the line insulators. This usually requires an arrester at every second or third pole. In the case of a feeder supplying a highly critical load, or a feeder with high ground resistance, it may be necessary to place arresters at every pole.

3.3.3 Low-Side Surges

Some utility and end-user problems with lightning impulses are closely related. One of the most significant ones is called the ―low-side surge‖ problem by many utility engineers. The name was coined by distribution transformer designers because it appears from the transformer's perspective that a current surge is suddenly injected into the low-voltage side terminals. Utilities have not applied secondary arresters at low-voltage levels in great numbers.

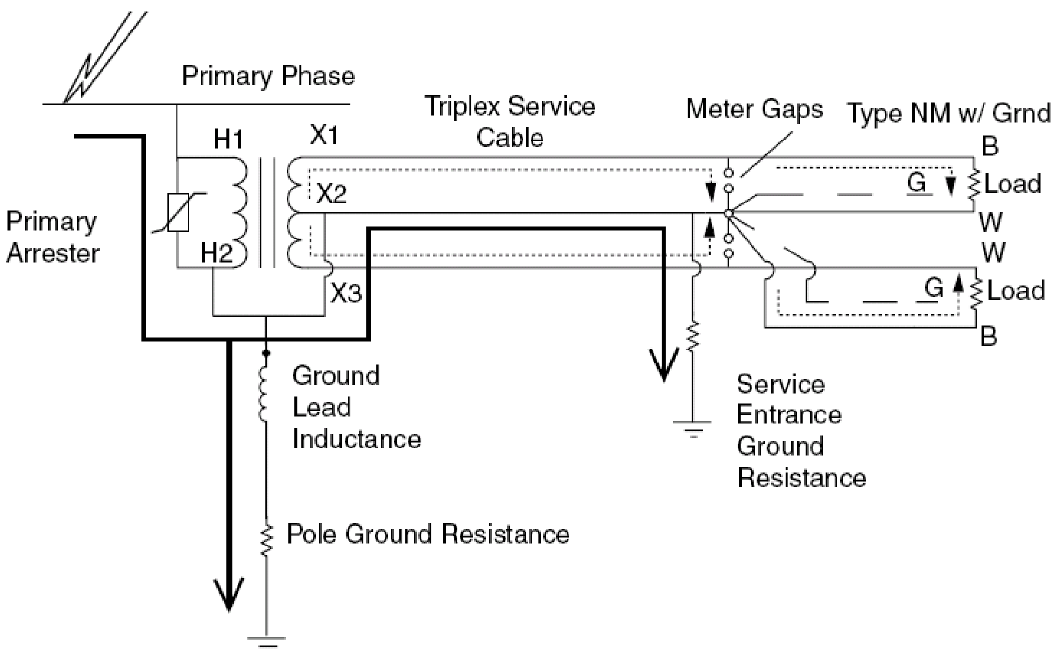

Figure 3.26 Primary arrester discharge current divides between pole and load ground

Both problems are actually different side effects of the same surge phenomenon lightning current flowing from either the utility side or the customer side along the service cable neutral.

Figure 3.26 shows one possible scenario. Lightning strikes the primary line, and the current is discharged through the primary arrester to the pole ground lead. This lead is also connected to the X_2 bushing of the transformer at the top of the pole. Thus, some of the current will flow toward the load ground. The amount of current into the load ground is primarily dependent on the size of the pole ground resistance relative to the load ground.

The current that flows through the secondary cables causes a voltage drop in the neutral conductor that is only partially compensated by mutual inductive effects with the phase conductors. Thus, there is a net voltage across the cable, forcing current through the transformer secondary windings and into the load as shown by the dashed lines in Fig.3.26. If there is a complete path, substantial surge current will flow. As it flows through the transformer secondary, a surge voltage is induced in the primary, sometimes causing a layer-to-layer insulation failure near the grounded end. If there is not a complete path, the voltage will build up across the load and may flash over somewhere on the secondary.

The amount of voltage induced in the cable is dependent on the rate of rise of the current, which is dependent on other circuit parameters as well as the lightning stroke.

The chief power quality problems this causes are

1. The impulse entering the load can cause failure or mis-operation of load equipment.

2. The utility transformer will fail causing an extended power outage.

3. The failing transformer may subject the load to sustained steady state over-voltages because part of the primary winding is shorted, decreasing the transformer turns ratio.

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