Cable Protection

One increasingly significant source of extended power outages on underground distribution (UD) systems is cable failures. The earliest utility distribution cables installed in the United States are now reaching the end of their useful life. As a cable ages, the insulation becomes progressively weaker and a moderate transient overvoltage causes breakdown and failure.

Many utilities are exploring ways of extending the cable life by arrester protection. Cable replacement is so costly that it is often worthwhile to retrofit the system with arresters even if the gain in life is only a few years. Depending on voltage class, the cable may have been installed with only one arrester at the riser pole or both a riser pole arrester and an open-point arrester (see Fig. 3.28).

To provide additional protection, utilities may choose from a number of options:

1. Add an open-point arrester, if one does not exist.

2. Add a third arrester on the next-to-last transformer.

3. Add arresters at every transformer.

4. Add special low-discharge voltage arresters.

5. Inject an insulation-restoring fluid into the cable.

6. Employ a scout arrester scheme on the primary (see Sec. 4.5.5).

The cable life is an exponential function of the number of impulses of a certain magnitude that it receives, according to Hopkinson. The damage to the cable is related by

$$D = N\, V^{C}$$

Where *D* = constant, representing damage to the cable

N = number of impulses

V =magnitude of impulses

c = empirical constant ranging from 10 to 15

Therefore, anything that will decrease the magnitude of the impulses only slightly has the potential to extend cable life a great deal.

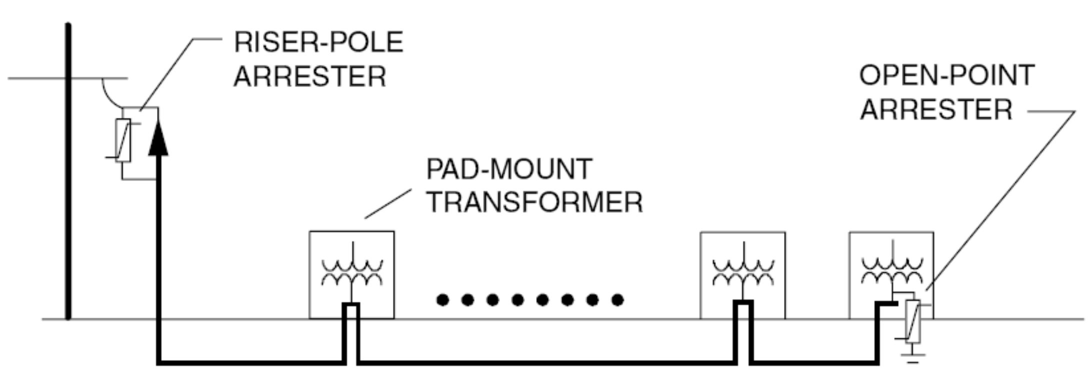

Figure 3.28 Typical UD cable arrester application

3.5.1 Open-point arrester

Voltage waves double in magnitude when they strike an open point. Thus, the peak voltage appearing on the cable is about twice the discharge voltage of the riser-pole arrester. There is sufficient margin with new cables to get by without open-point arresters at some voltage classes. While open-point arresters are common at 35 kV, they are not used universally at lower voltage classes.

When the number of cable failures associated with storms begins to increase noticeably, the first option should be to add an arrester at the open point if there is not already one present.

3.5.2 Next-to-last transformer

Open-point arresters do not completely eliminate cable failures during lightning storms. With an open-point arrester, the greatest overvoltage stress is generally found at the next to- last transformer. Figure 4.36 illustrates the phenomenon. Before the open-point arrester begins to conduct, it reflects the incoming wave just like an open circuit. Therefore, there is a wave of approximately half the discharge voltage reflected back to the riser pole. This can be even higher if the wave front is very steep and the arrester lead inductance aids the reflection briefly.

This results in a very short pulse riding on top of the voltage wave that dissipates fairly rapidly as it flows toward the riser pole. However, at transformers within a few hundred feet of the open point there will be noticeable additional stress. Thus, we often see cable and transformer failures at this location.

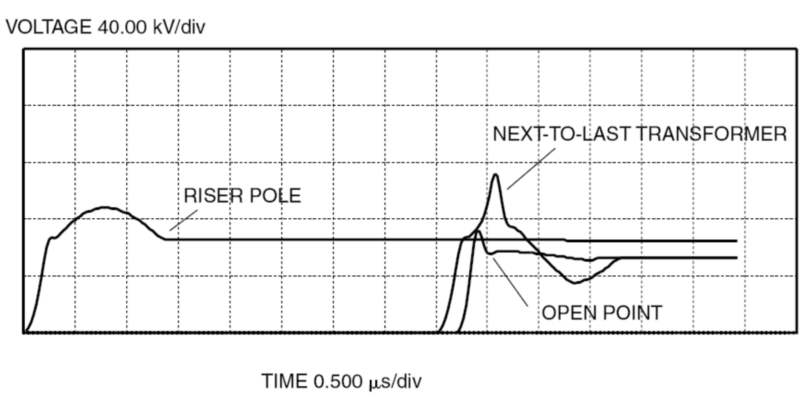

Figure 4.36 Impulse voltages along a cable with an open-point arrester showing that the peak can occur at the next-to-last transformer. Simulation with UD Surge computer program

The problem is readily solved by an additional arrester at the next to- last transformer. In fact, this second arrester practically obliterates the impulse, providing effective protection for the rest of the cable system as well. Thus, some consider the most optimal UD cable protection configuration to be three arresters: a riser-pole arrester, an open-point arrester, and an arrester at the transformer next closest to the open point. This choice protects as well as having arresters at all transformers and is less costly, particularly in retrofitting.

3.5.3 Under-oil arresters

Transformer manufacturers can supply pad mounted transformers for UD cable systems with the primary arresters inside the transformer compartment, under oil. If applied consistently, this achieves very good protection of the UD cable system by having arresters distributed along the cable. Of course, this protection comes at an incremental cost that must be evaluated to determine if it is economical for a utility to consider.

3.5.4 Elbow arresters

The introduction of elbow arresters for transformer connections in UD cable systems has opened up protection options not previously economical. Previously, arrester installations on UD cable systems were adaptations of overhead arrester technology and were costly to implement. That is one reason why open-point arresters have not been used universally. The other alternative was under-oil arresters and it is also very costly to change out a pad-mount transformer just to get an open-point arrester. Now, the arrester is an integral part of the UD system hardware and installation at nearly any point on the system is practical. This is a particularly good option for many retrofit programs.

3.5.5 Lower-discharge arresters

The gapped MOV arrester technology described earlier in this chapter was developed specifically to improve the surge protection for UD cables and prolong their life. The arresters are able to achieve a substantially lower discharge voltage under lightning surge conditions while still providing the capability to withstand normal system conditions. By combining the gaps from the old SiC technology with fewer MOV blocks, a 20 to 30 percent gain could be made in the lightning protective margin. The gaps share the voltage with the MOV blocks during steady-state operation and prevent thermal runaway. Following the logic of the Hopkinson formula, presented at the beginning of this section, converting to this kind of arrester in the UD cable system can be expected to yield a substantial increase in cable life.

3.5.6 Fluid injection

This is a relatively new technology in which a restorative fluid is injected into a run of cable. The fluid fills the voids that have been created in the insulation by aging and gives the cable many more years of life. A vacuum is pulled on the receiving end and pressure is applied at the injection end. If there are no splices to block the flow, the fluid slowly penetrates the cable.

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