

## Protecting the Transformer

There are two common ways for the utility to protect the transformer:

1. Use transformers with interlaced secondary windings.
2. Apply surge arresters at the X terminals.

Of course, the former is a design characteristic of the transformer and cannot be changed once the transformer has been made. If the transformer is a non interlaced design, the only option is to apply arresters to the low-voltage side.

Note that arresters at the load service entrance will not protect the transformer. In fact, they will virtually guarantee that there will be a surge current path and thereby cause additional stress on the transformer.

While interlaced transformers have a lower failure rate in lightning prone areas than noninterlaced transformers, recent evidence suggests that low-voltage arresters have better success in preventing failures.

Figure 3.27 shows an example of a well-protected utility pole-top distribution transformer. The primary arrester is mounted directly on the tank with very short lead lengths. With the evidence mounting that lightning surges have steeper wave fronts than previously believed, this is an ever increasing requirement for good protection practice.<sup>10</sup> It requires a special fuse in the cutout to prevent fuse damage on lightning current discharge. The transformer protection is completed by using a robust secondary arrester. This shows a heavy-duty, secondary arrester adapted for external mounting on transformers. Internally mounted arresters are also available. An arrester rating of 40-kA discharge current is recommended. The voltage discharge is not extremely critical in this application but is typically 3 to 5 kV. Transformer secondaries are generally assumed to have a BIL of 20 to 30 kV. Gap-type arresters also work in this application but cause voltage sags, which the MOV-type arresters avoid.



**Figure 3.27** Example of a distribution transformer protected against lightning with tank-mounted primary and secondary arresters.

### 3.4.1 Impact on load circuits

Figure 3.28 shows a waveform of the open-circuit voltage measured at an electrical outlet location in a laboratory mock-up of a residential service. For a relatively small stroke to the primary line (2.6 kA), the voltages at the outlet reached nearly 15 kV. In fact, higher-current strokes caused random flashovers of the test circuit, which made measurements difficult. This reported experience is indicative of the capacity of these surges to cause Overvoltage problems. The waveform is a very high frequency ringing wave riding on the main part of the low-side surge. The ringing is very sensitive to the cable lengths. A small amount of resistive load such as a light bulb would contribute greatly to the damping. The ringing wave differs depending on where the surge was applied, while the base low-side surge wave remains about the same; it is more dependent on the waveform of the current through the service cable.

One interesting aspect of this wave is that the ringing is so fast that it gets by the spark gaps in the meter base even though the voltage is 2 times the nominal spark over value. In the tests, the outlets and lamp sockets could also withstand this kind of wave for about 1  $\mu$ s before they flashed over. Thus, it is possible to have some high Overvoltages propagating throughout the system. The waveform in this figure represents the available open-circuit voltage. In actual practice, a flashover would have occurred somewhere in the circuit after a brief time.

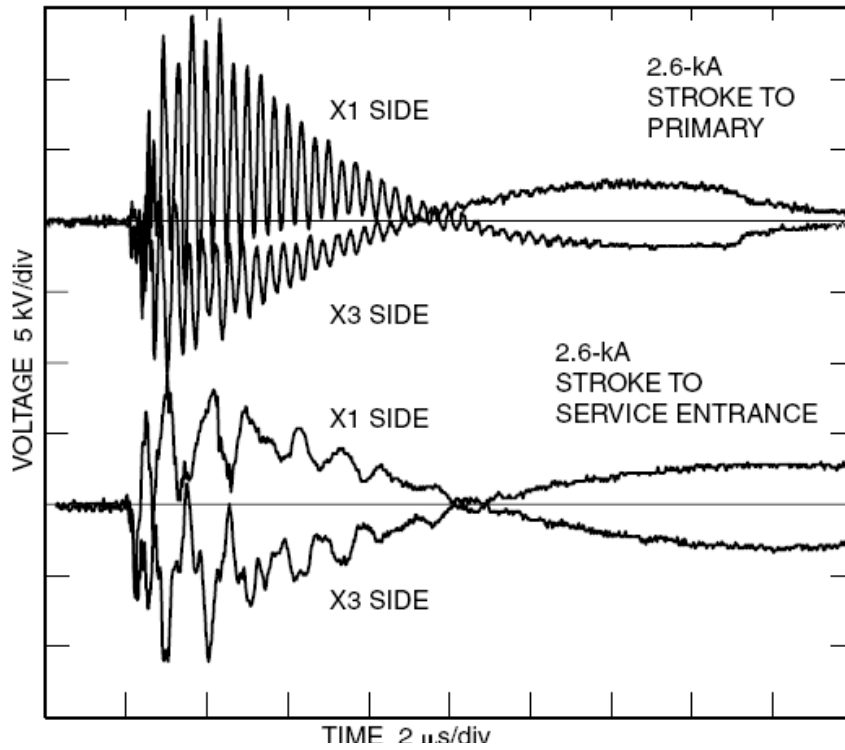
MOV arresters are not entirely effective against a ringing wave of this high frequency because of lead-length inductance. However, they are very effective for the lower-frequency

portion of this transient, which contains the greater energy. Arresters should be applied both in the service entrance and at the outlets serving sensitive loads. Without the service entrance arresters to take most of the energy, arresters at the outlets are subject to failure. This is particularly true of single MOVs connected line to neutral. With the service entrance arresters, failure of outlet protectors and individual appliance protectors should be very rare unless lightning strikes the building structure closer to that location than the service entrance.

Service entrance arresters cannot be relied upon to protect the entire facility. They serve a useful purpose in shunting the bulk of the surge energy but cannot suppress the voltage sufficiently for remote loads. Likewise, the transformer arrester cannot be considered to take the place of the service entrance arrester although it may be only 50 ft (15 meters) away. This arrester is actually in *series* with the load for the low-side current surge. The basic guideline for arrester protection should always be followed: Place an arrester directly across the insulation structure that is to be protected. This becomes crucial for difficult to- protect loads such as submersible pumps in deep water wells. The best protection is afforded by an arrester built directly into the motor rather than on the surface in the controller.

Some cases may not have as much to do with the surge voltage appearing at the outlet as with the differential voltage between two ground references. Such is the case for many TV receiver failures. Correct *bonding* of protective grounds is required as well as arrester protection.

The protective level of service entrance arresters for lightning impulses is typically about 2 kV. The lightning impulse current-carrying capability should be similar to the transformer secondary arrester, or approximately 40 kA. One must keep in mind that for low-frequency Overvoltages, the arrester with the lowest discharge voltage is apt to take the brunt of the duty. MOV-type arresters will clamp the Overvoltages without causing additional power quality problems such as interruptions and sags.



**Figure 3.28** Voltage appearing at outlet due to low-side surge phenomena

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