

Presented to ESEERCO EMF Task Force

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Introduction

Utilities today are faced with a different climate than 20 years ago. Today, they must deal with power quality and environmental issues while facing increased competition. Protection of line insulation from lightning with surge arresters (Protecta*Lite by Ohio Brass) can allow a utility to:

1. Improve power quality
2. Reduce EMF
3. Reduce cost.

This paper looks at the characteristics of four 138kV line designs and will demonstrate the advantages of using shieldless, arrester protected construction.

Shielded Construction

The use of a shield wire to intercept direct strokes and prevent them from hitting a phase wire is the most common protection method, although not the most effective.

Figure 1 defines the shield angle of a line. A line is "effectively shielded" if the shield angle is 30 degrees or less. Even with an effectively shielded line, shielding failures of 5 percent are common.

When a shielding failure occurs, the high voltage on the phase conductor causes the insulation to flashover. An overcurrent device must operate to interrupt the flow of system current. The flashover results in a service interruption for users connected to the line.

A stroke to shield wire is discharged to ground through the structure ground wire. A voltage in the tower develops that is a function primarily of the ground resistance and stroke current ($V=IR$).

Surge voltage is induced in the phase conductors and sufficient voltage difference may develop across the line insulation to cause a flashover. This is known as a backflash.

Backflash can be especially harmful to the performance of distribution underbuild circuits. A taller line (extra height due to shield wire) is hit by lightning more often than a shorter line. Possibly, the addition of a shield wire to a previously unshielded line may cause the lightning performance to become worse.

Surge Arrester Protection

Gapless MOV arresters are commonly used to protect non-air insulation, such as transformers from overvoltages.

This same principle can be applied to air insulation. The surge arrester used for the Protecta*Lite is designed to limit the surge voltage from a 40 kA lightning stroke to 435 kV. This is well below the flashover voltage of 138kV line insulation.

Since these arresters only conduct significant currents for the duration of a surge, they will not cause a breaker operation.

Figure 2 shows the relative duration of various surges and shows an arrester will operate too fast to be detected by protective relaying.

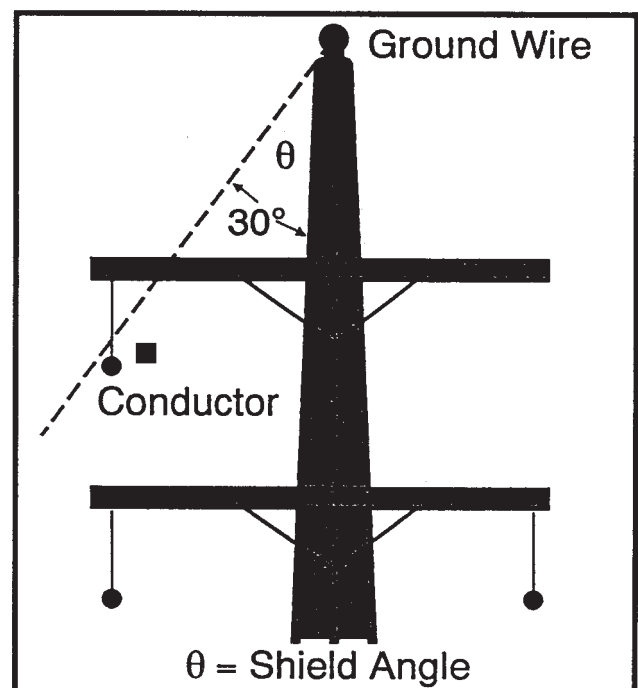


Figure 1

Line Designs

This paper will consider four different 138V designs. Figures 3-6 show the details of these designs. The designs are the traditional shielded H-Frame and Vertical Delta designs plus two unshielded delta configurations.

The following assumptions are made in studying these lines:

- Line Length = 100 miles
- Isokeraunic level = 30
- Footing resistance = 50 ohms
- Span length = 300* feet
- Conductor diameter = 1.00"
- Conductor sag = 4.5'
- Shield wire diameter = .375"
- Shield wire sag = 2.3'
- Insulator positive critical flashover = 675kV
- Phase-phase voltage = 138kV
- Height for field calculation = 3 feet
- Phase current = 800A
- Shield wire current = 0A

*520 feet for H-Frame

Lightning Performance

The lightning performance of these lines were studied using the proprietary Ohio Brass TLP software package.

The actual lightning performance in a given year depends on many factors including the lightning activity in the area and ground resistance. What is most important in the study is the degree of improvement that can be achieved by different protection methods.

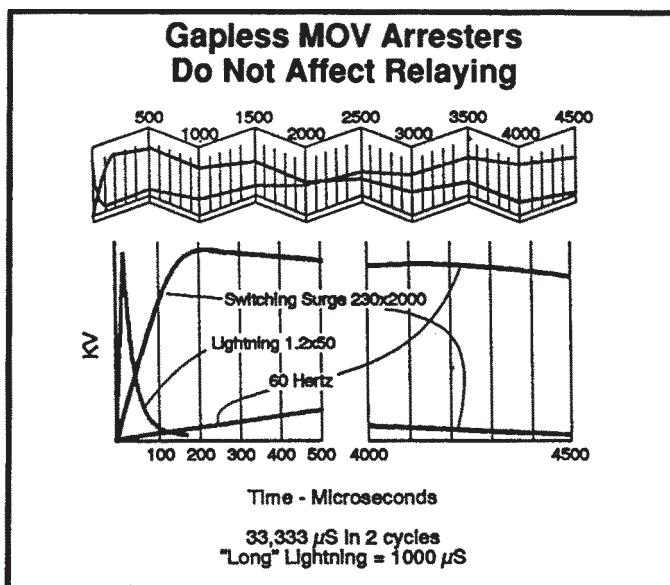


Figure 2

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The results of the study are summarized in the following table:

Figure	Construction Type	Average Annual Flashovers
3	H-Frame	7.8
4	Vertical Delta	6.5
5	Short Delta*	6.0
6	Tall Delta*	6.4

*Arresters on top phase, every other pole

The H-Frame has the worst flashover rate due to its larger shadow width and poor voltage coupling factors. This leads to backflashes from strokes to the shield wire.

The short delta has the lowest profile, the best coupling and the best lightning performance.

The performance of the delta line could be further improved by the addition of more surge arresters. These would first be applied to the remaining top phase insulators. The maximum protection can be achieved by arresters on all three phases. Figures 7 and 8 show how these arresters would be applied.

Magnetic Field Performance

The magnetic field around the line depends highly on the conductor geometry and the conductor height above the ground.

According to the EPRI Blue Book, the right of way for an H-Frame is 90 feet and only 60 feet for the delta type lines.

The line was studied using the Southern California Edison Company Fields Program.

As with the lightning performance we can see that the H-Frame has the worst performance. The tall delta has the lowest magnetic field level due to the additional structure height.

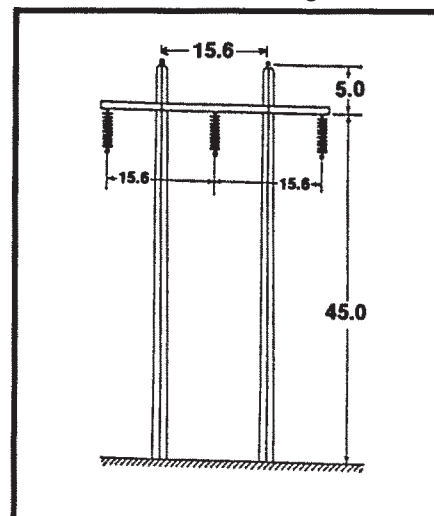


Figure 3

The table below summarizes the results of this study:

Figure	Construction Type	Magnetic Field (mG) Distance from Centerline (feet)				
		-45	-30	0	30	45
3	H-Frame	46.3	69.4	103.9	69.4	46.3
4	Vertical Delta	13.3	20.0	33.3	20.0	12.9
5	Short Delta	12.6	19.3	33.5	19.3	12.6
6	Tall Delta	10.7	15.3	23.0	15.3	10.7

Construction Costs

The EPRI Blue Book Chapter 8 presents a methodology for estimating the construction cost of transmission lines.

The following assumptions were made to obtain our estimate:

- Poles/mile = 17.60*
- Pole class = 2
- Suspension insulator = \$155
- Post insulator = \$275
- Protecta*Lite arrester = \$360
- Labor Cost = \$30/hr.

*H-Frame = 10.20

The Blue Book procedure was applied to these cases. The results are summarized below:

Figure	Construction Type	Pole Height (ft)	Cost Per Mile
3	H-Frame	60	\$63,750
4	Vertical Delta	60	61,000
5	Short Delta	50	56,170
6	Tall Delta	55	57,280

Summary

The Short delta construction protected by surge arresters on the top phase presents the utility with the best lightning performance and lowest cost. When compared to the H-Frame, significant reduction in the magnetic field is also achieved.

The Tall delta offers the lowest magnetic field strength plus low cost and good lightning performance.

By utilizing new technologies, utilities can obtain lower cost without sacrificing performance.

Many utilities are currently using this concept successfully at various voltages, which are covered in the suggested reading selections.

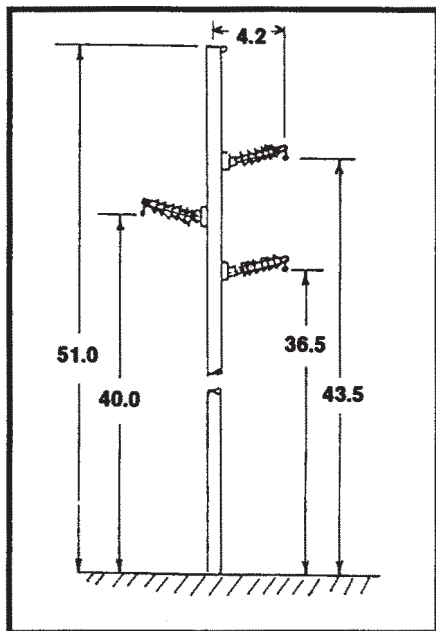


Figure 4

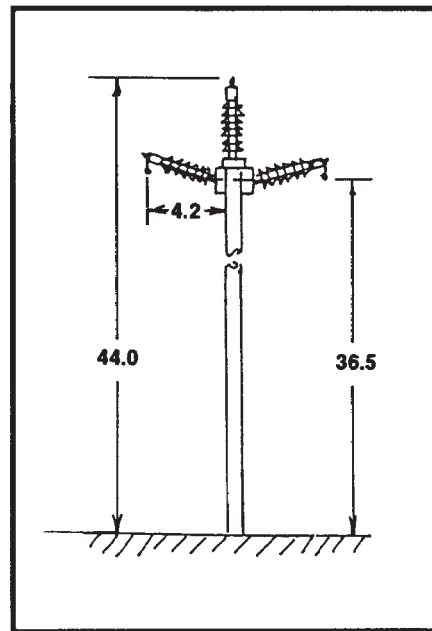


Figure 5

Additional Readings

1. IEEE Working Group on Estimating the Lightning Performance of Overhead Lines, "IEEE Design Guide for improving the Lightning Performance of Transmission Lines" (Proposed IEEE P 1243 draft dated October 1992).
2. Paul M. Ross, "BIL'S, TIL'S, TRANSIENTS AND LIGHTNING ARRESTERS," Ohio Brass Publication No. 2196-HR.
3. C.F. Wagner and G.D. McCann, "Wave Propagation on Transmission Lines," Electrical Transmission and Distribution Reference Book, Chapter 15, Westinghouse Electric Corporation, East Pittsburgh, PA, Fourth Edition, 1964.
4. C.F. Wagner and G.D. McCann, "Lightning Phenomena," *ibid.* Chapter 16.
5. A.C. Monteith, "Line Design Based Upon Direct Strokes," *ibid.* Chapter 17.
6. A.C. Monteith and H.R. Vaughn, "Insulation Coordination," *ibid.* Chapter 18.
7. Transmission Line Reference Book 115-138 kV Compact Line Design, Section 6, Electric Power Research Institute, Palo Alto, CA, 1978.
8. Canadian Standards Association Committee D308, Insulation Co-ordination, "The Principles and Practice of Insulation Co-ordination.
9. "Arrester Application on Double-Circuit Transmission Line," Bill R. Bonny, John G. Dalton, Duke Power Company.
10. E.J. Los, "Transmission Line Lightning Performance with Surge Suppressors at Towers," IEEE paper A 78 532-4 presented at the IEEE PES Summer Power Meeting, 1978.
11. AIEE Committee Report, "Application and Performance of 13-138 kV Line Expulsion Lightning Arresters (Line Protector Tubes)," AIEE paper 53-16 presented at the AIEE Winter General Meeting, 1953.
12. Harold S. Brewer, "Reduction of Lightning Caused Interruptions on Electric Power Systems," First International Conference on Power Quality, Societe des Electriciens et des Electroniciens, October 15-18, 1991.
13. Nick Bledsoe, "115 kV Line Protectors at Georgia Power Company," Hi-Tension News Magazine, Fall 1988.

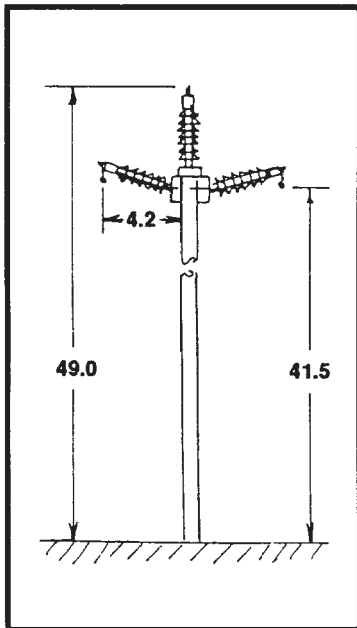


Figure 6

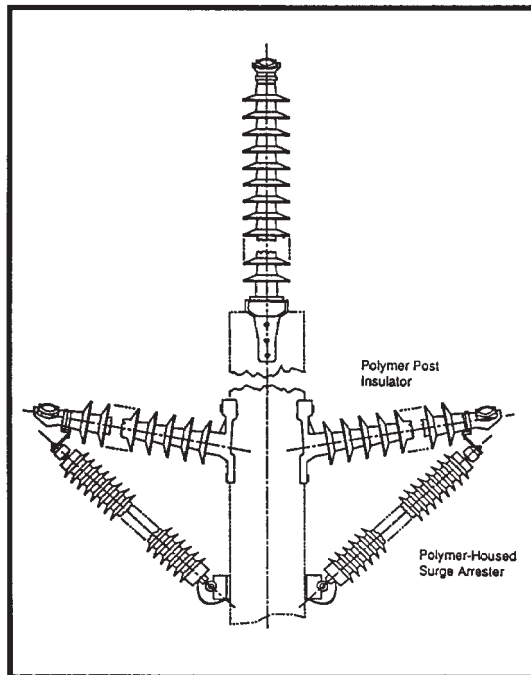


Figure 7

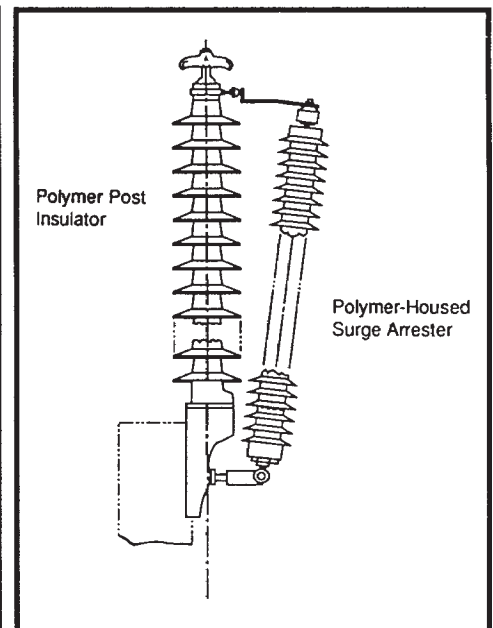


Figure 8