New Directions in Power Transmission

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ABOUT THE AUTHOR

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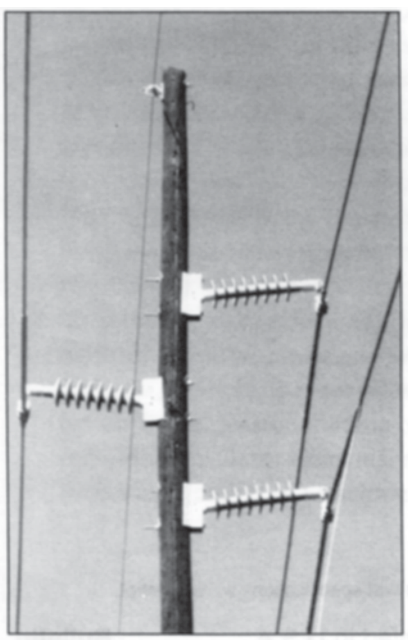

Figure 1
Malta line with delta configuration

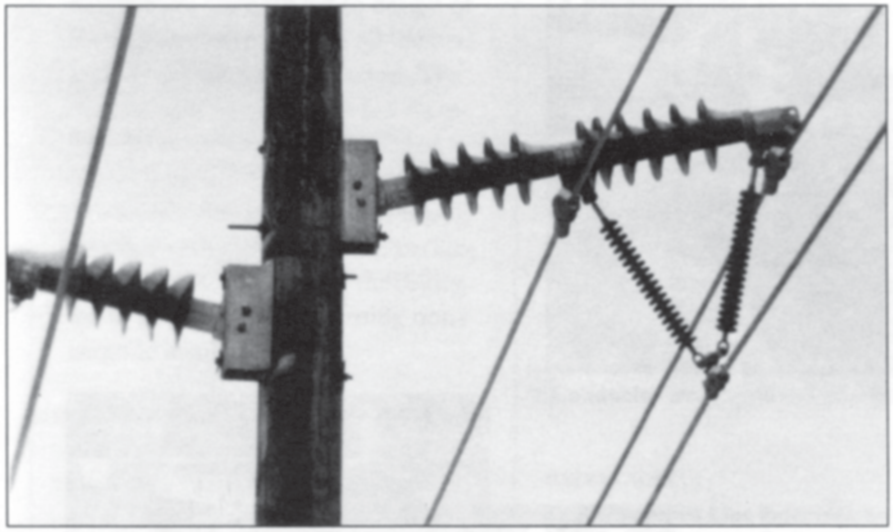

Figure 2 Bundled circuit insulator configuration

For a number of years, progress in power transmission was related to increasing voltage. Improvements in knowledge of insulation performance under steady state and transient conditions, corona and noise studies, and other research led to a steady rise in maximum system voltage. At the same time, 69-230 kV lines continued to be built in much the same way as they had since the earliest days. This can be seen in the relation of conductor spacing to the air gap distance required to withstand the power frequency voltage. While 765 kV lines were constructed with phase spacing 6.2 times the flashover spacing, 138 kV lines were still being constructed with phase spacing 10.5 times the flashover spacing. Increasing environmental and land use constraints, especially in urban areas, led to increasing design sophistication to reduce space requirements for lines in the 115-138 kV range, voltages frequently used to supply congested load areas.

EHV research focused primarily on electrical properties at higher voltages. Line compaction for 115138 kV built on this research and applied it to lower voltage lines under the basic premise: “If you designed a 138 kV line using 765 kV technology, what would you get?” An immediate result was the need for additional information concerning conductor motions due to wind, ice and fault currents. This information was developed in an EPRI-sponsored project which resulted in publication of **Transmission Line Reference Book 115-138 kV Compact Design** and subsequent reports.

6-phase Ohio Brass Hi*Lite insulators on test line

The need to reduce conductor motions led to the need for conductor restraint at the structures, a condition which is most easily met with the use of post insulators. Advantages of non-ceramic insulators immediately became apparent: light weight, ease of installation, and freedom from cascading failure. An installation on a prototype line is shown in Figure 1.

Non-ceramic designs allow construction of post insulators with multiple attachment points. These, in turn, give designers additional freedom in selecting conductor configurations, as in Figure 2. Two or more conductors can be supported by a single post, giving additional compaction and the ability to install circuits in tight locations. This additional compaction is partly due to the elimination of grounded conducting objects in the space between conductors, meaning that phase-to-ground clearance for two conductors is not required in the inter-conductor space.

While still a research topic, the combination of special insulator configurations with covered conductor gives promise of still further reductions in phase spacing for 69138 kV lines.

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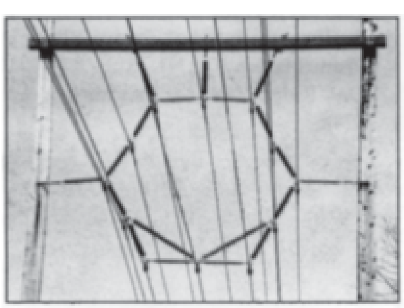
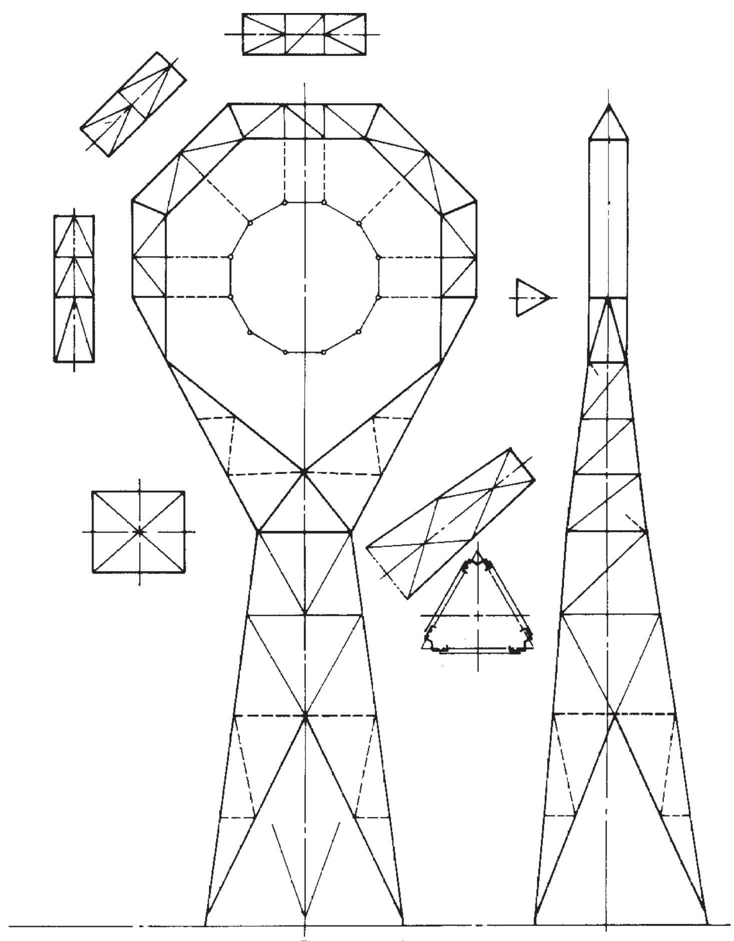


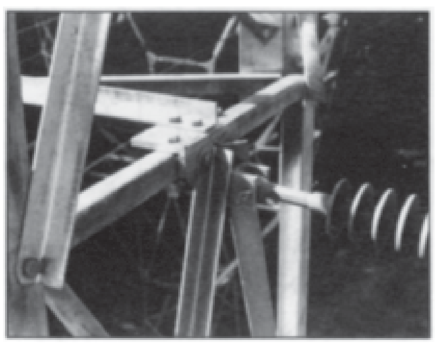
12-phase Hi*Lite hexagonal insulators



Sketch of SAE tower and insulator configuration

Transmission line compaction is making use of the latest technology to transmit the largest amount of power in the smallest space. This trend can be extended by increasing the number of phases per circuit. A study sponsored by the U.S. Department of Energy concluded the optimum use of space for transmission line conductors would have the conductors placed around the perimeter of the area allocated for their use and energized with voltages with the same number of electrical degrees between conductors as there are space angle degrees between conductors. This is a way to increase power density through approximately 12 phases, after which diminishing returns set in, so 12 appears to be the practical limit.

The design principles of compact lines hold true to a greater extent for a greater number of phases. Insulator conductor support systems must meet several functional requirements: symmetrical (approximately circular) conductor configuration, no grounded structural material within the conductor array, and restraint of conductor motion at the structures. The symmetrical conductor configuration and lack of conducting material in the conductor array are essential to the proper electric field distribution to utilize the air dielectric most effectively. In addition, to reduce insulator weight and cost, these further requirements are desirable: tension loading of individual insulator elements, and minimum number of attachment points to the structure. Initial concepts included post insulators, but questions of providing that number of attachment points with sufficient mechanical strength led to design of insulation systems where all the insulator elements were in tension. The requirement for no grounded members in the conductor array led to portal towers. The ability to design insulators with special end fittings coupled with contamination performance, light weight, and flexibility, led to prototype designs using non-ceramic insulators.



Tower attachment of phase-ground insulator

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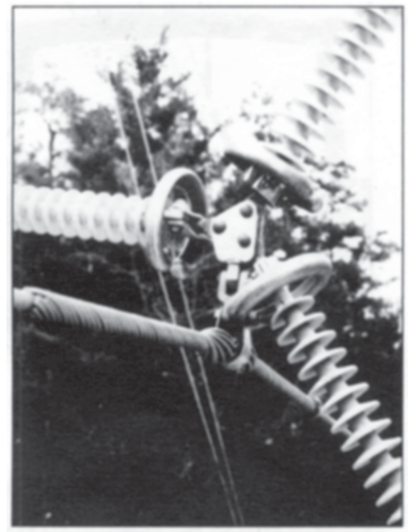

Conductor attachment on 12-phase line

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