

Considerations for loading BRACED LINE POSTS

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Traditionally, transmission insulators were suspended from tower arms. Because both insulators and tower arms serve as mechanical supports, a natural progression was to use insulators to replace structure arms. Initial efforts toward this end involved using line post insulators. The concept is attractive on several fronts. The utilization of line posts as insulating structure arms reduces the overall size of support towers. Additionally, by eliminating the traditional I-string, the design is able to more tightly fix the position of the conductors in space, thus reducing the required right-of-way width and assuring appropriate climbing clearances.

Early designs were manufactured with porcelain and were used for voltages 69 kV and below. The designs were gradually expanded to accommodate higher voltages by increasing the length of the insulator. As the section lengths (and applied voltages) increased, the line posts were required to support higher moments. Fortunately, the cross-sections (diameter) of the posts could be adjusted to achieve appropriate cantilever strengths. Unfortunately, the weight of the insulators increased with diameter.

Because the primary loading direction of concern was vertical, a triangular structural assembly was conceived that would address the shortfalls of the line post design. The line post and the existing support structure were used as two legs of the triangle. The third leg was created by adding an upward angled brace insulator from the line end of the line post to the tower to buttress the vertical strength and place the line post in a purely compressive loading situation. A universal-joint was included at the ground end of the line post to eliminate cantilever loading of the post member and an offset from the tower face was added to the ground end of the suspension insulator to impart stability. This design was called a Horizontal Vee. It resembles the pivoting horizontal-V, one of three variations of the braced line post shown on the following page.

Increased weight concerns were additionally alleviated in the mid-1970s when Non-Ceramic Insulators (NCIs) were introduced. In contrast to porcelain's high compressive strength, NCIs utilize the high tensile strength capabilities of unidirectional fiberglass rod. The high tensile strength of fiberglass rod allows NCIs to have a relatively small core rod diameter while offering equivalent cantilever strength to porcelain. As a result, NCI line posts offer strength equivalent to porcelain at about a third the weight of porcelain line posts. NCI line posts also offer an additional benefit of flexibility in comparison to their brittle porcelain counterparts.

Despite any advantages resulting from the substitution of NCIs for porcelain line posts and braced line post assemblies, additional considerations are necessary regarding the loading of these assemblies. Combinations of loading coupled with the flexibility of NCIs make it

necessary to consider all of these design factors:

- Tension loading of the brace insulator string
- Compression loading of the line post insulator
- Magnitude of the load applied to the line end fitting
- Total moment applied to the line post insulator

The mechanical advantage of specifying a braced line post assembly is its vertical loading capability. Each of the above listed items must be considered with respect to expected vertical loads to ensure the weakest component is not overloaded. The lowest resulting load then becomes the rated vertical capability of the assembly.

The load magnitude on the line end fitting and the applied moment on the line post insulator will be fairly straightforward constraints. Design considerations are more complex for the first two factors from our list: tension and compression on the brace and post insulators, respectively. Braced line posts are specifically intended for combined loading, meaning that these two factors must be closely considered in assembly design. It is the resultant load of the combined tension and compression that will lend design constraints.

Determining tension bearing capability of the brace string would seem simple because the strength of the tensile suspension insulator is typically known. Assuming that all of the components of the brace string have rated ultimate strengths equal to or exceeding that of the suspension insulator, the maximum working load of the suspension insulator would be the maximum design tension of the brace. However, there is one caveat to consider in that the loadings cannot exceed the rating of the weakest link in any of the components of the brace string. In designing a braced post assembly, an engineer must be certain to evaluate the tension rating for each component of the brace string before assuming that the suspension's working load is the only limiting factor.

Not only must an engineer account for the components of vertical force on the brace string, but the post's ability to handle the compressive loads resulting from a vertical load must also be evaluated. An NCI post insulator's relatively small core rod diameter makes it susceptible to elastic buckling when subjected to large compressive loads. Elastic buckling is, in part, a function of the slenderness ratio (length/radius) for the core rod used in the line post design. While elastic buckling may not be an issue for a relatively short line post, it may limit the loadings available for designs intended for voltages above 230 kV. As a guideline, the applied compressive loading on the post should never exceed 80% of the calculated elastic buckling load.

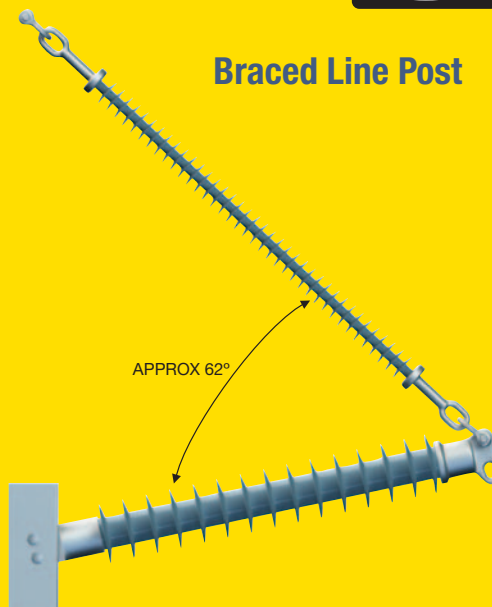
Elastic buckling load is calculated from Euler's buckling equation, which has variables that are best determined empirically. Ohio Brass/ Hubbell Power Systems has performed full scale tests to evaluate the elastic buckling potential of our braced line post assemblies. These tests are detailed in "Composite Braced Line Posts-Mechanical Considerations," which can be found on the website listed below.

A braced line post offers significant performance improvements over a standard line post. However, there are limitations to the capability of the assembly, the foremost being elastic buckling of the line post subassembly. As long as loadings are kept within the constraints of the weakest link of the assembly, mechanical issues should not arise and the improvements in mechanical strength associated with these designs can be employed.

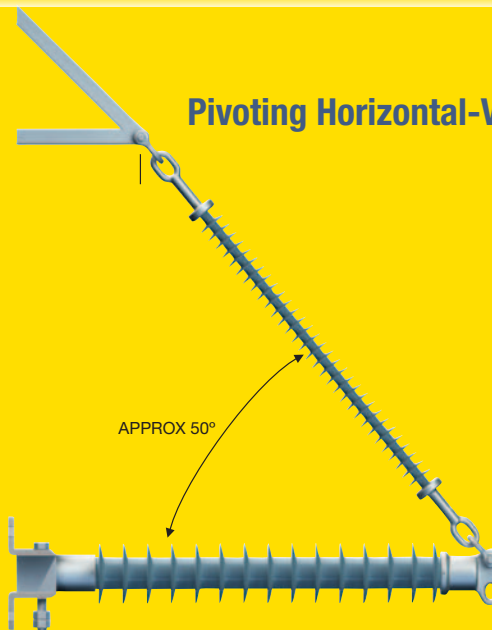
To read more about braced line post design or the use of application curves to evaluate the working range of an assembly, please find a copy of R.A. Bernstorff's full paper at <http://hubbellpowersystems.com/literature/insulators>.

The modern braced line post design can be varied based on strength and flexibility requirements. The braced line post, pivoting horizontal-V, and horizontal-V are each options to consider in transmission line design.

Braced Line Post



Pivoting Horizontal-V



Horizontal-V

