TRANSMISSION AND SUBSTATIONS

MANAGEMENT OF COMPOSITE STRUCTURES

Introduction and Background

Poles and crossarms manufactured from fiberglass-reinforced polymer (FRP), alternatively called composites, are increasingly gaining acceptance for utility distribution and transmission line applications. Compared to traditional materials, composites have a fairly short history of service as a fabrication material for utility structures; consequently, little data is available of their performance over time. The first composite poles for utility use were installed in the 1960s for a low voltage distribution application. These poles lasted about 45 years and were then removed from service due to deterioration of their physical appearance resulting from ultraviolet (UV) degradation. Material and construction technologies have significantly improved in recent years, as have additives for UV protection, and some manufacturers are now claiming service lives of 60 to 80 years for their products.

Structures manufactured from composite materials are not widely used for high voltage applications (above 230kV). Some reasons for this can be attributed to the greater amount of deflection under load compared to steel and concrete, and also the lack of knowledge of how the material performs in a high electric field environment.

Why Composites

Because of their inherent characteristics, composite structures are lighter than wood and steel pole equivalents. The comparative ease of transportation and installation can make them ideal for recovery efforts from hurricanes, ice storms and other extreme weather events or disasters, and for delivery and emplacement using helicopters. Composite poles are stronger than wood poles of a similar size, and as the material is engineered, their material properties are more consistent than wood. Their increased flexibility can permit the absorption of shock loads should the installa-

Contents

tion be impacted by storm damage. Some utilities include composite poles in wood pole installations by installing them at intervals of every 5th or 6th pole to eliminate the risk of cascading failures.

Other advantages of composites over traditional materials include corrosion resistance, non-leaching of chemicals, impervious to biodegradation, resistance to animal attack (woodpeckers), and the material requires lower maintenance.

The initial purchase cost of composite poles is higher than wood. However, manufacturers claim they have longer life expectancy, and advertise ranges from 60 to 80 years. In addition, smaller installation equipment is needed due to the lighter weight of the composite poles when compared with wood, and maintenance requirements are significantly less.

Modular poles are manufactured using a filament winding process whereby multiple layers of polymer-impregnated glass fibers are wrapped around a tapered mandrel, which is then placed in an oven to cure.

One-piece poles, as well as crossarms, are manufactured using the pultrusion process, which involves the polymer-impregnated glass fiber being fed into and through a heated die that controls the internal and external shape of the component. It cures in the die and is pulled through by grippers – hence the name pultrusion.

Industry Challenges

Potential barriers to increased usage of this material include unknown aging or degradation mechanisms, lack of product standardization, lack of guidance for inspection/assessment practices, and lack of field experience with the material, particularly at voltages of 230kV and above. Unlike for example steel or concrete, there is no standard that defines how the product is manufactured. Although there are similarities in materials used, each manufacturer uses proprietary additives and processes.

Understanding the modes of failure, degradation rates, and the environmental factors that start the degradation process, will be instrumental to the adoption of this technology. Extensive testing is required to develop an understanding of the material properties and how they change over time. In addition, review of vendor and utility knowledge of field testing, utility demonstration projects, and in-service composite structures increases awareness of existing lessons learned. However, due to the relatively short history of the use of composites for the construction of utility poles and crossarms, little data is currently available of their performance over time.

There is no "one size fits all". As mentioned, several manufacturing techniques, and a range of different component materials are used by the various manufacturers of composite poles and crossarms. In addition, there are two types of pole configurations; modular and one-piece. In other words, all poles are not created equal.

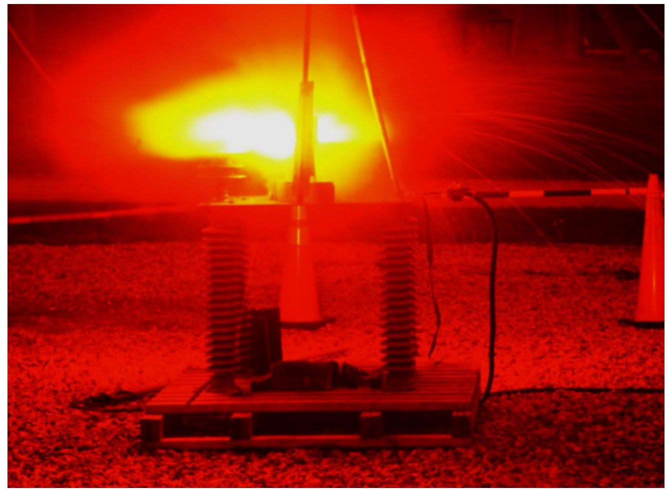
What EPRI is Doing

This need for increased knowledge regarding composite pole performance has led to the development of a multi-year test regimen being undertaken by EPRI. The objective of this work is to enable utilities to have a greater knowledge of the characteristics of the material, how these can be applied, and the differences between products from the various manufacturers. Best practices for selection, specification, design, installation, inspection/assessment, and refurbishment are being developed. Comparative testing is being performed in many areas to enable a good understanding of the responses of the material to environmental, electrical and mechanical stresses.

EPRI has identified a number of knowledge gaps that may influence the adoption of the technology, and in response has developed a comprehensive test program to address these. Some of these tests, together with references to their associated reports, are listed below.

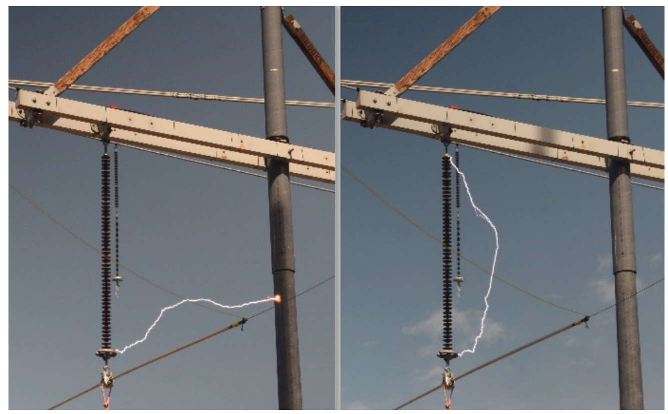
- Accelerated aging of both full-scale and small-scale composite poles and crossarms – each of the manufacturer's poles are aged in custom aging chambers. Small scale samples are also being aged in a commercial aging cabinet and results compared1.
- Mechanical testing to determine changes in properties due to aging – new and artificially aged poles are tested to failure and results compared to determine performance over time1.

Accelerated Aging of Composite Poles



Arc Flash Testing - Composite Pole Sample

Composite Pole Undergoing Testing to Failure



Insulation Coordination Testing of 230kV Composite Structure

- Effects of temperature extremes on mechanical properties – composite properties are affected by temperature. Tests at temperatures ranging from -40°C to 60°C have been performed[2].
- Effects of simulated wildfire exposure on mechanical properties – samples from composite poles have been subjected to flame temperatures and durations equivalent to wildfire exposure tests, and subsequently mechanically tested to evaluate changes[3]. In addition, their self-extinguishing properties were noted.
- Susceptibility to electrical tracking – inclined plane tests performed to evaluate comparative tracking performance[4].
- Long term corona impingement – comparative performance of samples subjected for twelve months to corona in a dry atmosphere, and likewise in a humid atmosphere[5].
- Effects of arc flash puncture on pole integrity – pole sections from each manufacturer were punctured by power frequency arcs. Test coupons were taken from the area adjacent to puncture and subjected to mechanical testing to determine any effects resulting from the localized heating[6].
- Insulation coordination of composite structures – flashover performance of composite H-frames in both 138kV[7] and 230kV[8] geometries were evaluated with different insulator lengths, gap distances and grounding configurations, for both wet and dry conditions. Resulting component damage was identified, and recommendations made.
- Maintenance and inspection recommendations – a review of manufacturer recommended, as well as utility procedures for maintenance and inspection of composite structures[9].

Summary

There is significant opportunity to improve the resiliency of overhead lines and reduce total ownership costs by using composite structures. Poles and crossarms manufactured from this material can provide many unique benefits over components produced from traditional materials.

EPRI aims to continue the research into composite structures and the material properties to provide utilities with the information needed to address the knowledge gaps, and to improve their confidence in adopting this technology.

References (partial list of reports)

1. *Full-scale Aged Composite Poles: Condition Review and Testing to Failure*. EPRI, Palo Alto, CA: 2018. 3002012628.
2. *Effects of Temperature on Strength and Deflection of Composite Pole Materials*. EPRI, Palo Alto, CA: 2020. 3002018914.
3. *Effects of Fire Damage on Composite Pole Materials*.EPRI, Palo Alto, CA: 2020. 3002018916.
4. *Small-Scale Testing of Composite Pole Samples: Evaluation of Handling, Environmental, and Electric Field Exposure Effects*. EPRI, Palo Alto, CA: 2015. 3002005648.
5. *Combined Environmental and Electric Field Exposure of Composite Pole Samples*. EPRI, Palo Alto, CA: 2016. 3002007681.
6. *Results of Small-scale Tests of Composite Pole Samples*. EPRI, Palo Alto, CA: 2017. 3002010118.
7. *Insulation Coordination of Composite Crossarm Structures – 138kV*. EPRI, Palo Alto, CA: 2019. 3002015602.
8. *Insulation Coordination of Composite Crossarm Structures – 230kV*. EPRI, Palo Alto, CA: 2020. 3002018915.
9. *Inspection and Maintenance of Composite Poles*. EPRI, Palo Alto, CA: 2020. 3002018917.

Technical Contact

Martin Hughes at 413.445.3705, mhughes@epri.com.

3002020576 February 2021

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA • 800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com