Technical Information

Composite Conductor

795-kcmil

Sheave Testing of 795 ACCR Conductor with Helical-Rod Full-tension Splices

Investigators:

Dr. Colin McCullough, 3M Company

Mr. Todd Staffaroni, 3M Company

Mr. Robert Parker, Sherman & Reilly, Inc.

Sheave Testing of 795 ACCR Conductor with Helical-Rod Full-tension Splices

June, 2006

Colin McCullough & Todd Staffaroni, 3M
Rob Parker, Sherman & Reilly

Executive Summary

Access restrictions that would prevent splicing of line sections in an installation at Xcel Energy, led to tests to see if helical-rod full-tension splices provided by PLP (Preformed Line Products) could be safely pulled-in over sheaves when already spliced on the conductor. Suitable sheave configurations were found that could safely allow passage of fully configured splices under angles and tensions that exceeded the likely Xcel Energy installation conditions. Confidence was gained that Xcel Energy could proceed with the installation using this pre-spliced approach and overcome the lack of field access.

Background

A ten (circuit) mile line section of 795 kcmil 3M™ Composite Conductor was to be installed by Xcel Energy in their transmission network. Late difficulties arose in obtaining the necessary field access to the line in order to apply splices. Specifically, two sections, one of 25,000 feet (19 spans), one of 17,000 feet (12 spans), was denied DNR access to the mid-span regions between towers where the splices would be applied to join consecutive sections of conductor. Thus, it was necessary to determine whether fully configured full tension splices could be applied at one end of the line section and then pulled through all the sheaves to the other end, thus permitting a pre-spliced line section to be installed.

Of great concern was that the splices are relatively rigid compared to the conductor and posed a potential core fracture risk at the transition between splice and conductor when pulled over a bending arc such as a sheave. This is a most unusual installation practice – seldom used even in steel reinforced conductors for the same fears of conductor damage.

Alcoa-Fujikura splices composed of steel and aluminum tubing were rejected as being too rigid. PLP (Preformed Line Products) splices are made from helical wound rods of aluminum alloys and are more flexible and these were thought to provide the best opportunity at passing through sheaves without conductor damage. They are also already qualified for use with the 795 kcmil 3M™ Composite Conductor.

Installation Requirement

The Xcel Energy line had long spans between the towers, characterized by a 1400 ft ruling Span. Long span lengths create large break-over angles at both suspension towers and at the first tower (where the conductor pays off a spool on the ground and rises to the first tower). The expected typical angles and tensions are characterized in Figure 1. The final sag was at ~5500 lbs (17.5% RBS tension), and it was predicted to take ~2500 lbs (8% RBS tension) just to prevent sag onto the ground. Pulling tensions were 10-12% RBS tension which may climb to 14.5% RBS with frictional drag from the sheaves. The angles produced from these tensions are in the range of 15-22 degrees at the suspension towers, and 25-30 degrees at the first sheave assuming a 1:3 ratio in set-up from the tower. If the set-up distance shrinks to 1:2, then the first tower angles increase by 8 degrees. Thus, these are the conditions that the splice and spliced conductor has to endure in order to pass safely through the installation process.

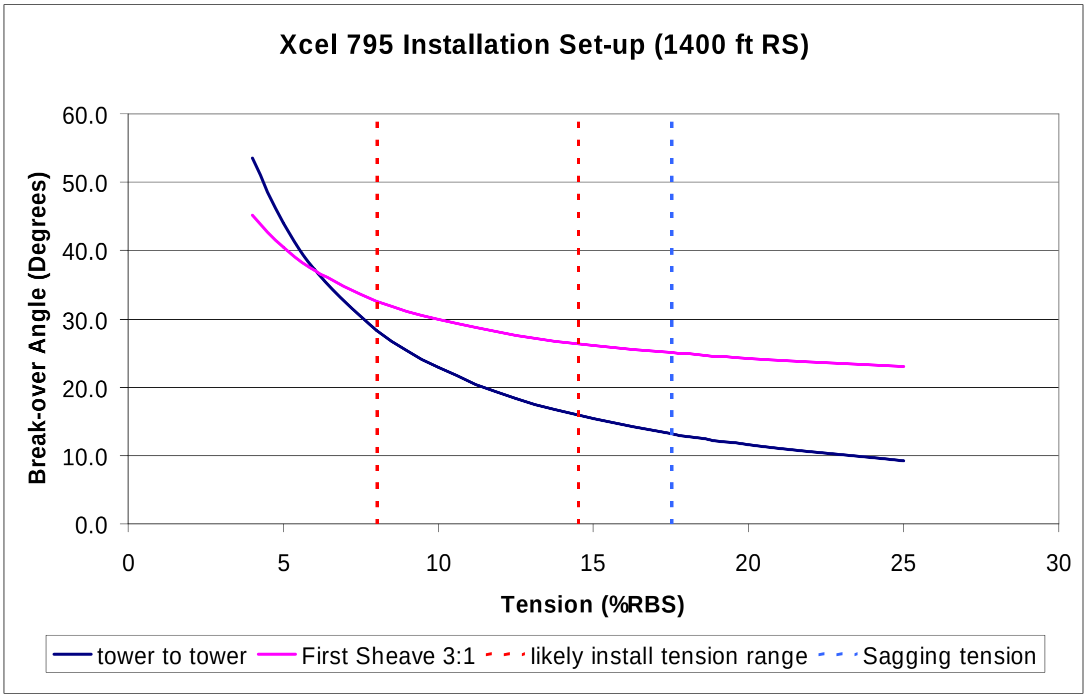

Figure 1. Calculated expected angles and tensions for the installation.

Goals

The purpose of these tests was to explore the use of:

(a) Roller Arrays for use on the first tower where the angles are highest
(b) A single 36-inch sheave for use at suspension towers

Testing Arrangement

The field installation arrangement at Sherman & Reilly, Chattanooga, TN, uses a loop defined by three sheaves (Figure 2). The 55-inch diameter Anchor sheave is actually the drive sheave that drives the loop in a single direction. The 55-inch diameter Pull sheave is connected to a puller that applies tension to the loop. The test sheave is selected as desired. Break-over angles are set either by changing the position of the Pull sheave or by adjusting the loop length, which has the net effect of moving the Pull anchor in the horizontal plane. Nominal angles were set in the field but then actual angles were accurately measured later by image processing of digital photographs.

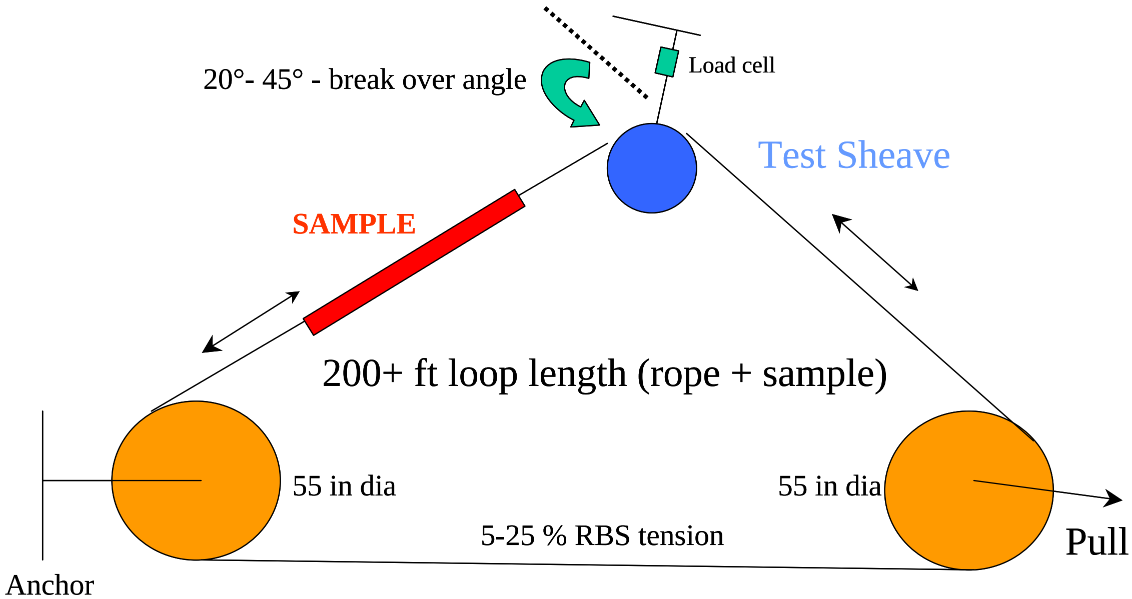

Figure 2. Sheave Test Configuration

Resultant tension (R) on the test sheave is monitored through a load cell and the line tension (T) is then computed from this using the equation:

$$T = R/2\sin(\Theta/2)$$

where Θ is the break-over angle.

The length of the loop is nominally 200 ft but is adjusted by removing or splicing in length as needed. Most of the loop is strung with a Uniline pulling line (low stretch rope), and the sample is spliced into the loop using pulling grips. Each end of the pulling line is terminated with wire-mesh pulling grips and each end of a 40 ft long conductor piece is terminated with a wire-mesh pulling grip. The conductor piece was further cut into two 20 ft sections and then re-connected using a two layer PLP ThermolignTM full-tension splice, part number TLSP-795 (Figure 3). Two splices were available for testing, each of which was used twice. The ends of the rods were taped to prevent catching on the sheaves.

Figure 3. Fully configured splice in the test loop

During the test, the sample was driven under tension in a clockwise direction over the sheave and then stopped to prevent from passage around the 55-inch sheaves. The tension was removed and the sample driven backwards through the block and then re-tensioned.

This was to more accurately simulate the field condition and also to protect the drive motor at the anchor sheave, which is not designed for reverse motion under tension. At each passage of the conductor and grips over the test sheave, any acoustic noise was listened for, in particular "clicks" which would suggest core wire breaks. The goal was to accumulate 20 passes of the configured loop over the test sheave for a suspension configuration or 3 passes for first tower configuration. After the test, the conductor and splice was removed from the loop and dissected into the individual wires for confirmation of safe passage or damage. During the test, the tension fluctuated due to stretch of the cables (both pulling line and conductor), and this was adjusted with the puller during the run. Thus the tension usually has a small range during the test.

Two Sheaves were tested (Figure 4). Firstly a Roller Array was used consisting of 6 small 7-inch diameter sheaves that laid out an arc of 45 degrees having a radius of 60 inches. Secondly a 36-inch sheave block was tried.

Figure 4. (a) roller array (b) single 36-inch sheave

Table I shows the resulting test matrix.

Test #	Sheave	Break-over angle (degrees)	Tension (%RBS)	Comment
1	Roller Array	30	10	3 Passes
2	Roller Array	35	15	3 Passes
3	Roller Array	40	10	3 Passes
4	36-inch sheave	20	15	20 Passes

Table I. Test Matrix for Sheave Tests

Test Results

Results are listed in Table II.

Test #	Actual break-over angle (degrees)	Tension (%RBS)	# Passes	Observations
1	29.6	9.7-11.0	3	No damage to Splice & Conductor
2	33.8	16.6-17.4	3	No damage to Splice & Conductor
3	39.0	10.1-10.6	3	No damage to Splice & Conductor
4	18.7	16.3-17.3	20	No damage to Splice & Conductor

Table II. Results of sheave tests for safe splice passage

In all cases, a good result was achieved. There was no damage to the core wires or the splice upon dissection (Figure 5). The splices were surprisingly flexible and suffered no signs of distortion.

Figure 5. Undamaged Conductor core wires after sheave testing.

The implications for the installation conditions are shown in Figure 6.

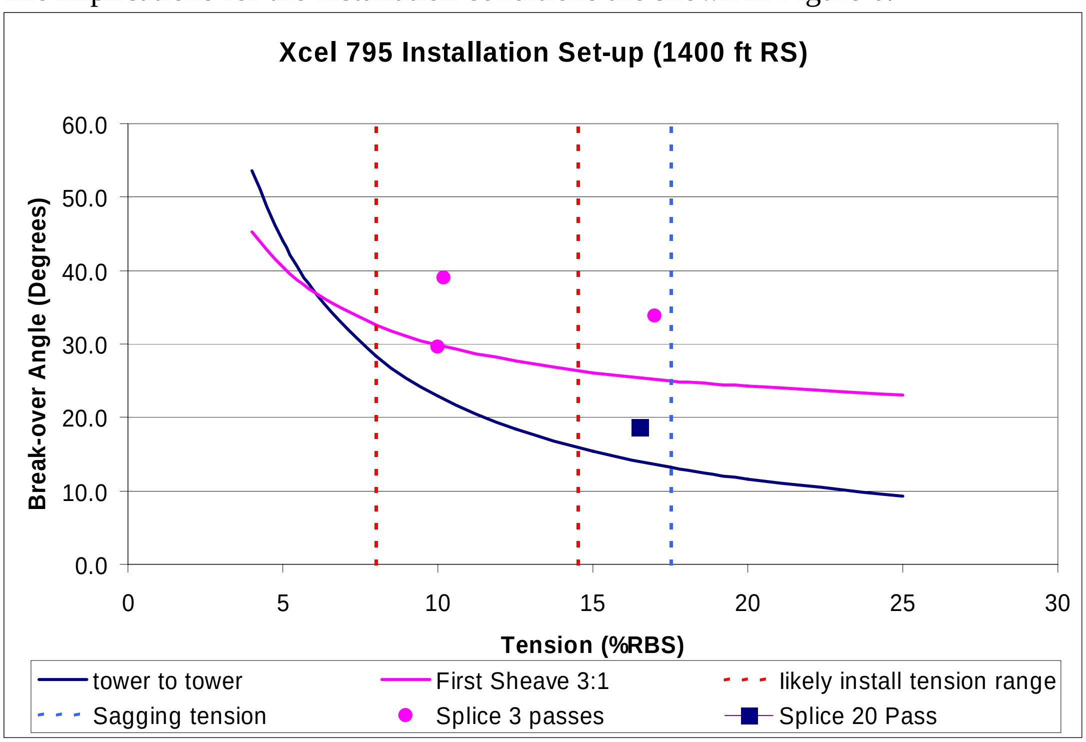

Figure 6. Test Data plotted with expected installation conditions.

The round symbols represent data from the roller array and pair with the curve for the first sheave (first tower). The splice & conductor assembly can endure higher angles and tensions than will be anticipated. If the field set-up was constrained at 2:1 then the angles would increase 8 degrees, but the test data suggests this would be tolerable. The square symbol is data from the 36-inch sheave used at suspension towers. This suggests the expected angles and tensions would be fine for safe passage of the splice & conductor assembly.

Conclusions

1. Conductor configured with a PLP full-tension splice passed over a roller array assembly 3 times without damage at angles up to 39 degrees/10% RBS tension and 34 degrees/17% RBS tension. This suggests a safe window for passage of the splice assembly over a roller array if used at the first tower during actual installation.

2. Conductor configured with a PLP full-tension splice passed over a 36-inch sheave 20 times without damage at an angle of 19 degrees/17% RBS tension. This suggests a safe window for passage of the splice assembly over multiple sheaves if used at suspension towers during the actual installation.

3. It is recommended to tape the ends of each layer of the splice assembly as a preventive measure against catching and popping out due to sheave contact.

4. Sufficient confidence has been gained to suggest the approach of installing conductor pre-spliced with PLP full-tension splices is a good solution to overcome the access restrictions on this installation.