DISTRIBUTION CONDUCTOR STRINGING

EQUIPMENT & TECHNIQUES

FOR THE 21ST CENTURY

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When the decision is made to build an overhead distribution power line, there are many factors which must be considered before the job is successfully completed. Right-of-way must be secured, supporting structures installed, conductor and hardware purchased, etc. All of the above is done with one objective, to safely place conductor in its final resting place, without damage, and have it remain there with little or no maintenance for a long period of time.

Great care is exercised in the selection of the supporting structures and associated hardware, and often very little attention is given to the handling of the item that should also have the highest priority. That item is the conductor. After all, the primary reason for the right-of-way, poles, hardware, etc., is to support that all important conductor.

The purpose of this paper is to emphasize the importance of including into the decision making process the equipment used to install the conductor. The importance of this cannot be overlooked when you consider that during construction some parts of the stringing system mechanically contact every inch of conductor. The only other time this happens is during the manufacture of the conductor as it passes through the stranding machine and goes onto a shipping reel.

For this discussion, we will consider the separate components which make up the stringing equipment used in building an overhead distribution power line.

There are four separate and distinct components involved and they are listed in their descending order of importance.

1. Tensioner
2. Bull Line (Pulling Line)
3. Stringing Blocks
4. Puller

When the four parts are used together, they have a definite relationship one-to-the-other, and consequently should be designed and manufactured to work together as a complete and compatible stringing system.

The important relationship that exists among the four components is often overlooked. If any one of the four is deficient in design or performance, it directly affects the other three.

An example would be an excellent tensioner, puller and stringing blocks, but a pulling line with too much elongation. This will result in a poor installation job. The excess stretch makes the tensioner difficult to control and the result is a conductor which slowly oscillates up and down while being pulled. Not only does it make the pulling of the conductor difficult, it also introduces variations in stress, not only to the other components in the stringing system, but also to such parts as poles and hardware. And don't forget the all important conductor.

Another example would be the travelers or stringing blocks. If they introduce excessive friction, the pulling force increases resulting in higher bull line tension. This increases the force the puller must generate, limiting its capability, and also could potentially surpass the pulling line working load causing it to fail prematurely. In addition, it increases the load on both hardware and supporting structures. And don't forget the all important conductor.

These examples apply equally to all four components in the stringing system. If one is deficient, the other three suffer. They must all be compatible and work safely together to be successful.

TENSIONER

The importance of the tensioner in a successful pulling operation is too often overlooked. Of the four basic components involved, the tensioner plays the most important part. Only the tensioner is capable of directly affecting the conductor tension, and any changes in conductor sag while pulling must originate with the tensioner.

Most stringing jobs today utilize a tensioner which accepts either a wood or metal reel and retards its rotation with some type of braking system. This can be mechanical, such as drum or disc brakes, or preferably a pure hydraulic retarding system. While mechanical braking systems will work, they possess many shortcomings making them less than ideal. Large amounts of energy are dissipated in the form of heat during the tensioning process and mechanical brakes tend to change or fade due to this heat build up, resulting in variations in conductor tension. Total hydraulic retarding systems are available today which can successfully dissipate this heat without these shortcomings.

State-of-the-art total hydraulic tensioning systems also give us the capability to make minute changes in conductor sag during tensioning, which allows work to be performed more safely in close clearance areas. Working over and under energized circuits is more common today than ever before and demands the best control possible of the conductor.

There is a basic rule that is often overlooked when tensioning directly from a conductor reel. Unlike the puller, where the required torque to maintain a given amount of pulling force increases as the drum fills, on the tensioner the reverse is true. For a given amount of conductor tension, it requires more braking action on a full reel and this reduces as the reel empties. So the relationship between puller and tensioner is that each is inversely proportional to the other throughout the pulling operation. This basic principal which applies when tensioning directly from a reel is among the least understood items in the stringing operation, particularly among the crews in the field.

BULL LINE

The bull line or pulling rope has historically been one of the more overlooked and abused parts of a successful pulling system. First of all, the bull line needs to be the smallest diameter possible for a given working load. Remember, that for a given amount of torque, as each additional layer of pulling line is wound on the drum, the pulling force goes down. Anything which helps avoid this build up is significant. Use of the smallest diameter possible along with only installing as much line as necessary to accomplish your pulls is an easy way to effectively upgrade the puller's capacity. If one mile pulls are the maximum, then only install a sufficient length to accomplish this rather than a longer length just because the drum will accept it. Always work as close to the drum core as possible.

Pulling lines are available today which have been designed and constructed specifically for pulling conductor. Three strand and braided type ropes, although of excellent quality, are a misapplication when stringing conductor. Because of their design, most contain an exceptional amount of constructional stretch or elongation along with rotational characteristics which make pulling a conductor with these ropes difficult. A length of rope 100-feet long, used for handlines, with ten percent elongation, presents no problem but a 6000-foot length of pulling line having 600-feet of stretch will destroy a good conductor pull.

STRINGING BLOCKS

The third most important item in a successful pulling operation is the traveler, dolly, or stringing block. As conductor is being pulled, it progressively passes through more and more travelers. The loss that takes place at each traveler, although small at each one, is cumulative. A major portion of the inefficiency or loss is due to the bending and straightening of the conductor as it passes over the stringing block at each suspension point. Consequently, sheave size becomes very important. Also, the type of bearings used, the sheave lining, pulling through angles, changes in elevation, etc., all contribute to the loss. These are all lumped together to establish a value which becomes the efficiency figure. The thing to keep in mind is that all losses in a given pull are additive. Even with the most efficient units there can be one-, two-, or three-percent loss. With a two-percent loss at each suspension point, which is about normal, after fifteen structures the total loss in the pull approaches thirty percent. If the loss is four percent at each structure, the total loss then becomes about fifty percent. The higher the loss, the greater the stress on equipment, structures and the conductor we are trying to protect. A successful pulling operation cannot tolerate a traveler or stringing block with high inefficiencies.

PULLER

The puller requires very little description as it is the least important of the four. Except for the fact that it must be capable of supplying adequate force to pull the conductor, there are only a few attributes it must possess.

1. It should be as small in physical size as possible to make it easy to maneuver and set up.

2. It should have adequate operator protection against failure of the pulling line.

3. It should be equipped with a device to levelwind the pulling line to assure the line builds on the drum in some order and also to allow for the inability to set up in an ideal location.

4. It should be equipped with some method for retarding the pulling line, without free wheeling, to allow the rehauling of the line to the tensioning end.

5. It should have the ability to allow the operator to make minute changes to the pulling force to just move the conductor and no more.

6. Pulling speed is not as important as its ability to pull smoothly with excellent control of both speed and force.

PULLER/TENSIONER

In recent years, the unit which has become the standard for most utilities is a machine which combines the features of both puller and tensioner. The advances in hydraulic components have made this possible. Now the industry has available a unit which has total hydraulic capabilities and can be used on either end of the job. It will accept a steel pulling drum to become a puller or it can accept a conductor reel and be a tensioner.

To be classified as a puller/tensioner, the unit should have the same capabilities in either application and direction. Unfortunately, this is not always the case, as there are units being offered under the class puller/tensioner which don't have identical capacities in both applications. These units will be hydraulic as pullers but use mechanical retardation for tensioning.

Along with having all the qualities of both a puller and a tensioner, puller/tensioners have numerous additional advantages. Some of these are as follows:

1. One unit capable of working either end.
2. Since both units can pull or tension, the conductor can move in either direction, with its many advantages.
3. The bull line can be tensioned during the rehaul process as if it were conductor with the tensioner doing the pulling.

4. It eliminates the need for as much equipment, such as line trucks with their winch capabilities, having to be tied up on the job site.

5. In an emergency, such a storm damage, the units can be split and used as needed as either puller or tensioner.

6. After a conductor is pulled in and terminated, the tensioner can pull back to assist in the sagging operation.

BULLWHEEL TENSIONERS

Any discussion of tensioning equipment would not be complete without mentioning the twin-capstan type method utilizing grooved wheels commonly referred to as bullwheels. This type of tensioning is essential when constructing transmission lines where the conductors are large, the spans are long, and particularly if it is bundled conductor. In the distribution area very few lines are built with bullwheel tensioners. The more popular arrangement is to tension directly from the reel on which the conductor is shipped. There is a rule of thumb which is accepted throughout the industry that states as long as the tension on the reels, whether wood or metal, does not exceed 1,000 pounds, it is acceptable to tension directly from a reel. With this in mind, as a general rule, you don't start looking at bullwheels until the conductor size approaches the 795-MCM area. Even then, it depends to a large degree on span length since many lines are constructed using 795-MCM and 954-MCM conductor on distribution spans while tensioning directly from conductor reels. If bullwheels are used, however, they should be of the multi-groove type (4 or 5 grooves) and not a single V-groove. Remember the all important conductor.

FORMULAS

There are several rather simple formulas that you should become familiar with for calculating both tension and pulling forces. They are known as the T_1 and Tmax formulas.

The first, for T_1 is:

$$T_1 = \frac{WL^2}{8D}$$

T = Tension in Conductor

W = Weight Per Foot of Conductor

L = Span Length in Feet

D = Sag in Feet

This formula allows you to calculate the tension required to support a conductor in a static condition in one span.

The second, for Tmax is:

$$Tmax = \frac{T}{.98n}$$

Tmax = Tension to Pull Conductor

.98 = Efficiency of Stringing Block

n = Number of Support Points

This formula allows you to calculate the actual pulling force required for any given situation using the inefficiency of the stringing block or traveler and the number of support points. With a 2-percent loss the value for "n" is .98, for a 3-percent loss use .97, etc. Examples for several conductors and span lengths along with different inefficiencies are shown on the following pages. Each one is based on 20 support points or 19 spans.

In the examples you will quickly notice what happens to the pulling force as the efficiency of the system drops. It is unlikely that the .90 figure would ever be realized. It is only listed to show what can happen and how the required force would rapidly increase. Each example shows the calculations for 20 support points and 4 different efficiency values.

The last chart includes the values for 2 through 20 support points with 4 different figures for efficiency. Notice that with only a 2-percent loss at each support, which is about normal, after 20 supports the loss totals one third of the pulling force.

I hope the above has been helpful, and if there are any questions I will be glad to try and answer them at this time.

Thank you and line up with S&R!!!

RAVEN 1/0 ACSR 6/1

The formula to determine the tension required to support conductor in one span:

$$T_1 = \frac{WL^2}{8D}$$

W = Weight per unit length of conductor.

D = Sag (during stringing phase).

L = Span length.

T_1 = Tension to support one span (in static condition).

<u>EXAMPLE</u>: 1/0 ACSR (6/1) 145.2 lbs. per 1000 ft.

W = .1452 lbs. per foot.

D = 2 feet.

L = 150 feet.

$$T_1 = \frac{.1452 \times (150 \times 150)}{2 \times 8} = \frac{.1452 \times 22{,}500}{16} = \frac{3267}{16}$$

$$T_1 = \frac{3{,}267}{16} = 204 \text{ lbs. Tension}$$

The formula to determine the tension required to pull the conductor.

$$T_{max} = \frac{T_1}{.98^n}$$

T_1 = Tension to support one (1) span.

.98 = Efficiency of stringing block.

n = Number of supports (blocks).

$$T_{max} = \frac{T_1}{.98^n} = \frac{204 \text{ lbs.}}{.6676} = 306 \text{ lbs.} \quad n = 20$$

$$.96^n = \frac{204 \text{ lbs.}}{.4420} = 462 \text{ lbs.} \quad n = 20$$

$$.94^n = \frac{204 \text{ lbs.}}{.2901} = 703 \text{ lbs.} \quad n = 20$$

$$.90^n = \frac{204 \text{ lbs.}}{.1216} = 1678 \text{ lbs.} \quad n = 20$$

LINNET 336.4 MCM ACSR 26/7

The formula to determine the tension required to support conductor in one span:

$$T_1 = \frac{WL_2}{8D}$$

W = Weight per unit length of conductor.

D = Sag (during stringing phase).

L = Span length.

T_1 = Tension to support one span (in static condition).

EXAMPLE: 336.4 ACSR (26/7) 463 lbs. per 1000 ft.

W = .463 lbs. per foot

D = 2 feet.

L = 150 feet.

$$T_1 = \frac{.463 \times (150 \times 150)}{2 \times 8} = \frac{.463 \times 22{,}500}{16} = \frac{10{,}417}{16}$$

$$T_1 = \frac{10{,}417}{16} = 651 \text{ lbs. Tension}$$

The formula to determine the tension required to pull the conductor.

$$Tmax = \frac{T_1}{.98^n}$$

T_1 = Tension to support one (1) span.

.98 = Efficiency of stringing block.

n = Number of supports (blocks).

$$Tmax = \frac{T_1}{.98^n} = \frac{651 \text{ lbs.}}{.6676} = 975 \text{ lbs.} \quad n = 20$$

$$.96^n = \frac{651 \text{ lbs.}}{.4420} = 1471 \text{ lbs.} \quad n = 20$$

$$.94^n = \frac{651 \text{ lbs.}}{.2901} = 2244 \text{ lbs.} \quad n = 20$$

$$.90^n = \frac{651 \text{ lbs.}}{.1216} = 5354 \text{ lbs.} \quad n = 20$$

DAHLIA 556.5 MCM, 19 STRAND ALL ALUMINUM

The formula to determine the tension required to support conductor in

one span:

$$T_1 = \frac{WL_2}{8D}$$

W = Weight per unit length of conductor.

D = Sag (during stringing phase).

L = Span length.

T_1 = Tension to support one span (in static condition).

<u>EXAMPLE</u>: 556.5 ACSR (19) 522 lbs. per 1000 ft.

W = .522 lbs. per foot.

D = 4 feet.

L = 200 feet.

$$T_1 = \frac{.522 \times (200 \times 200)}{4 \times 8} = \frac{.522 \times 40{,}000}{32} = \frac{20{,}880}{32}$$

$$T_1 = \frac{20{,}880}{32} = 653 \text{ lbs. Tension}$$

The formula to determine the tension required to pull the conductor.

$$Tmax = \frac{T_1}{.98^n}$$

T_1 = Tension to support one (1) span.

.98 = Efficiency of stringing block.

n = Number of supports (blocks).

$$Tmax = \frac{T_1}{.98^n} = \frac{653 \text{ lbs.}}{.6676} = 978 \text{ lbs.} \quad n = 20$$

$$.96^n = \frac{653 \text{ lbs.}}{.4420} = 1477 \text{ lbs.} \quad n = 20$$

$$.94^n = \frac{653 \text{ lbs.}}{.2901} = 2251 \text{ lbs.} \quad n = 20$$

$$.90^n = \frac{653 \text{ lbs.}}{.1216} = 5370 \text{ lbs.} \quad n = 20$$

ARBUTUS 795 MCM, 37 STRAND ALL ALUMINUM

The formula to determine the tension required to support conductor in one span:

$$T_1 = \frac{WL^2}{8D}$$

W = Weight per unit length of conductor.

D = Sag (during stringing phase).

L = Span length.

T_1 = Tension to support one span (in static condition).

EXAMPLE: 795 ALUM (37) 746 lbs. per 1000 ft.

W = .746 lbs. per foot.

D = 6 feet.

L = 250 feet.

$$T_1 = \frac{.746 \times (250 \times 250)}{6 \times 8} = \frac{.746 \times 62{,}500}{48} = \frac{46{,}625}{48}$$

$$T_1 = \frac{46{,}675}{48} = 971 \text{ lbs. Tension}$$

The formula to determine the tension required to pull the conductor.

$$Tmax = \frac{T_1}{.98^n}$$

T_1 = Tension to support one (1) span.

.98 = Efficiency of stringing block.

n = Number of supports (Blocks).

$$Tmax = \frac{T_1}{.98^n} = \frac{971 \text{ lbs.}}{.6676} = 1454 \text{ lbs.} \quad n = 20$$

$$.96^n = \frac{971 \text{ lbs.}}{.4420} = 2197 \text{ lbs.} \quad n = 20$$

$$.94^n = \frac{971 \text{ lbs.}}{.2901} = 3347 \text{ lbs.} \quad n = 20$$

$$.90^n = \frac{971 \text{ lbs.}}{.1216} = 7985 \text{ lbs.} \quad n = 20$$

DRAKE 795 MCM ACSR 26/7

The formula to determine the tension required to support conductor in one span:

$$T_1 = \frac{WL^2}{8D}$$

W = Weight per unit length of conductor.

D = Sag (during stringing phase).

L = Span length.

T_1 = Tension to support one span (in static condition).

<u>EXAMPLE</u>: 795 ACSR (26/7) 1094 lbs. per 1000 ft.

W = 1.094 lbs. per foot.

D = 6 feet.

L = 250 feet.

$$T_1 = \frac{1.094 \text{ x } (250 \text{ x } 250)}{6 \text{ x } 8} = \frac{1.094 \text{ x } 62,500}{48} = \frac{68,375}{48}$$

$$T_1 = \frac{68,375}{48} = 1424 \text{ lbs. Tension}$$

The formula to determine the tension required to pull the conductor.

$$Tmax = \frac{T_1}{.98^n}$$

T_1 = Tension to support one (1) span.

.98 = Efficiency of stringing block.

n = Number of supports (Blocks).

$$Tmax = \frac{T_1}{.98^n} = \frac{1424 \text{ lbs.}}{.6676} = 2133 \text{ lbs.} \quad n = 20$$

$$.96^n = \frac{1424 \text{ lbs.}}{.4420} = 3222 \text{ lbs.} \quad n = 20$$

$$.94^n = \frac{1424 \text{ lbs.}}{.2901} = 4909 \text{ lbs.} \quad n = 20$$

$$.90^n = \frac{1424 \text{ lbs.}}{.1216} = 11,711 \text{ lbs.} \quad n = 20$$

nth Power Chart
Two to Twenty Supports

		.98	.96	.94	.90
Power	2 =	.9604	.9216	.8836	.8100
	3 =	.9412	.8847	.8306	.7290
	4 =	.9424	.8493	.7807	.6561
	5 =	.9039	.8154	.7339	.5905
	6 =	.8858	.7828	.6899	.5314
	7 =	.8681	.7514	.6485	.4783
	8 =	.8508	.7214	.6096	.4305
	9 =	.8337	.6925	.5730	.3874
	10 =	.8171	.6648	.5386	.3487
	11 =	.8007	.6382	.5063	.3138
	12 =	.7847	.6127	.4759	.2824
	13 =	.7690	.5882	.4474	.2542
	14 =	.7536	.5647	.4205	.2288
	15 =	.7386	.5421	.3953	.2059
	16 =	.7238	.5204	.3716	.1853
	17 =	.7093	.4996	.3493	.1678
	18 =	.6951	.4796	.3283	.1501
	19 =	.6812	.4604	.3086	.1351
	20 =	.6676	.4420	.2901	.1216