How stays work

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When a pole has conductors and one or more stays attached, the components operate as one system, interacting with each other.

1 Introduction

Wood distribution poles have been traditionally modelled as a strut because they are quite flexible. A strut is a flexible object rotating about a pivot point and in the case of a

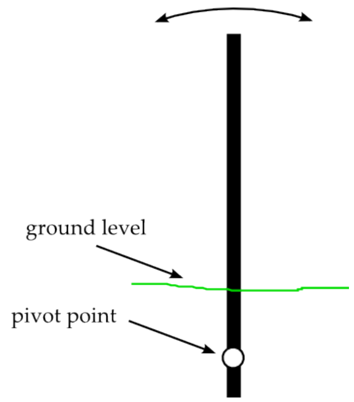

Figure 1: Pole as strut

pole the pivot point is usually at ground level, figure 1. Sometimes the pivot point is taken as below ground to reflect that the soil does provide some support.

A distribution pole is in static equilibrium. The loads on the pole and any resistance to those loads are balancing each other out. Loads are due to conductor tension and wind load on the pole and conductors, and resistance is provided by the pole itself and stays. The resistance given by the stay is passive so the stay cannot be modelled in the same way as conductors are modelled.

Figure 2 shows a simple case—a termination pole with a stay opposite the load. For the no wind case the net load on the pole is zero as the stay completely resists the load from the conductors. This assumes the pole pivots at ground level, as discussed above.

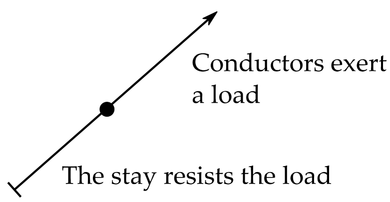

Figure 2: Termination pole

In figure 3 the stay resists the conductor load but does nothing to counteract the wind load since the wind load is perpendicular to the stay. That leaves a net load on the pole, which the pole needs to resist by its own strength. There is also wind load on the pole which is ignored in this example, but it is dealt with in the same way.

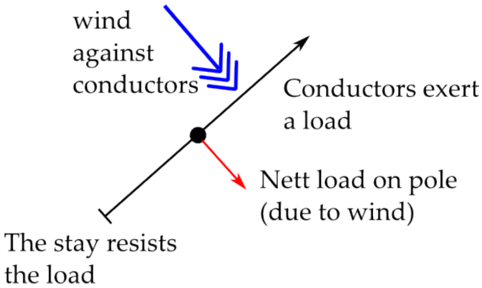

Figure 3: Conductor and wind load

Figure 4 shows how loads on poles are added as vectors[1]. All loads due to conductors and wind (which in this simple example are perpendicular) are added together vectorally to give a single resultant load. This resultant load (which is the unstayed tipload) is what is resisted by the stay.

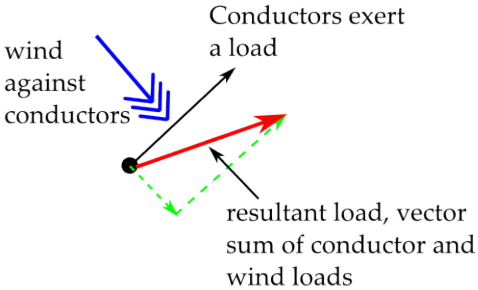

Figure 4: Vector sum of loads

Although the wind load is uniform along the pole, it can be modelled as a point load applied either at the midpoint of the pole height or at the centre of mass of the pole.

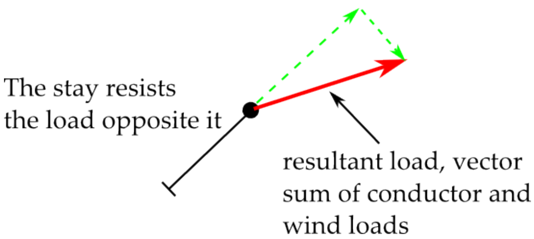

Figure 5: Resultant load resolved

Figure 5 shows the resultant load being resolved to two vectors, in line with the stay and perpendicular to it. The stay can only counteract loads opposite it, leaving just the component of the resultant load perpendicular to the stay, to be resisted by the pole it-

1 To calculate the tipload, equilibrium of forces and equilibrium of moments are both taken into account.

self.

These examples show what happens when there is a single conductor load and a wind load. The same process is followed when there are multiple conductor loads resisted by a single stay—all loads are vectorially added together, then that load (which would be reported as the tipload for the unstayed pole) is resisted by any stays on the pole.

For a pole that has one stay the pole acts as a strut[2] in the direction of the stay (pivoting at ground level, so the stay takes the full load) and as a cantilever[3] perpendicular to the stay— the pole does not pivot at ground level and resists the load perpendicular to the stay.

2 Two stays

The process is more complex when the resultant load is resisted by two stays but if the stays are positioned so that one is on each side of the load (figure 6), which is the ideal, they act together leaving a net load of zero. See section 4 for more comments about two stays.

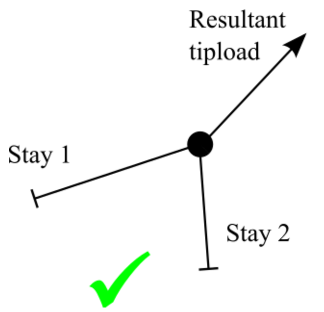

Figure 6: Two stays, balanced

3 A common misconception #1

What about the situation in figure 7? Figure 7 represents a pole with conductor loads in directions A and C with a stay in direction B. Does the stay cancel the effect of the conductor load C leaving only the conductor load A (assuming A, B and C are in the same horizontal plane)?

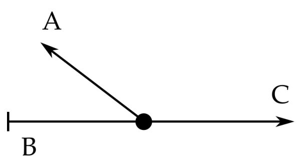

Figure 7

No. Figure 8 shows the addition of the two conductor loads giving a resultant load (in

2 Strut—a long slender member subject only to compression ie vertical load
3 Cantilever—a member fixed at one end

red). Figure 9 left shows resolving the resultant load in line with and perpendicular to the stay. The stay acts against the component of load opposite it, leaving the net load perpendicular to the stay (figure 9 right).

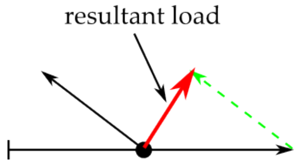

Figure 8

Figure 9

4 Assessment of two stays in the Tipload module

The above principles are used by the Tipload module in calculating the effectiveness of two stays. If the two stays are positioned so they are balanced against the tipload as shown in figure 6 the tipload will be zero and the load in each stay is reported. If only one stay is effective for any tipload calculation (tiploads are calculated for each wind direction according to the Increment setting in Options) that direction and tipload is stored by the program. After all calculations have been performed, if there is at least one direction for which only one stay was effective, the worst case tipload is reported in the results, along with the load in the effective stay.

The "balance" equations, which are independent of the properties of the pole and stay wires, are valid only when the stays are placed suitably. If the two stays are close to being in the same plane (ie both in line with the tipload) or are too far away from the opposite-to-load, additional information is needed to do the calculation. You will see a message when doing the tipload calculation if the stays are in an invalid configuration.

5 A common misconception #2

Figure 10 is a common stay arrangement. It works when lines are being installed but is not suitable when the installation is complete. Why?

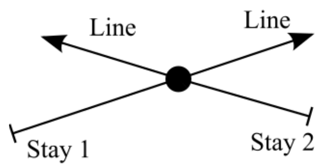

Figure 10: Back stays

The line conductor loads are vectorally added so the net load is approximately centred between the two lines. This means the stays are quite close to the load they are resisting. Figure 11 shows the relative efficiency[4] of a stay to resist a load, the X axis being the angle between the stay and the load (α_1 or α_2 in figure 12). You can see that a stay less than about 150° away from the tipload is substantially less efficient than a stay opposite the tipload (180°). Therefore stays installed as in figure 10 have negligible value for the intact (operational) load.

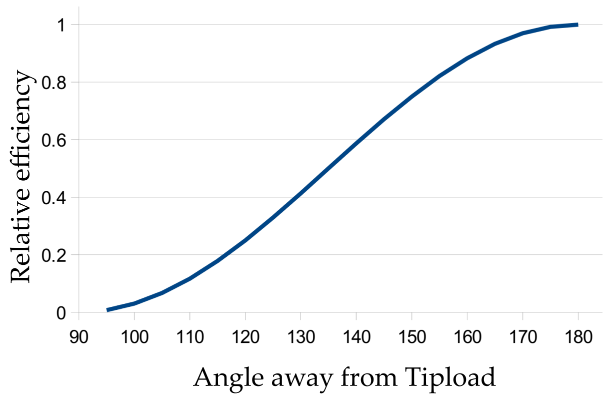

Figure 11: Relative efficiency of stay

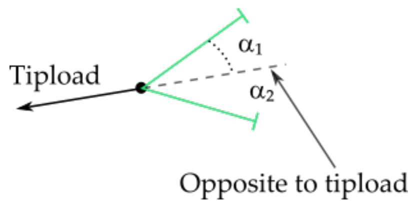

Figure 12: Angle between stay and opposite-to-tipload

Another way to look at it is to consider the tension in the stay wires as the stays swing

4 Section 5.2.2 *Design of Guyed Electrical Transmission Structures*. American Society of Civil Engineers

away from opposite the tipload. Figure 13 shows the tension in the stay wires for a pole with a 30kN load and two stays symmetrically positioned. The X axis is the angle between stay and the opposite of the tipload. When the stay is more than about 50° away the tension in the stay wire increases dramatically, exceeding its strength capacity.

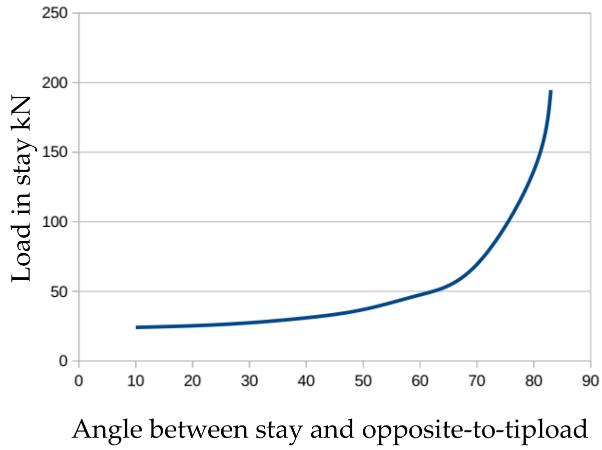

Figure 13: Tension in stay wires

These two considerations could lead to a rule of thumb not to position stays more than 30-40° away from the opposite of the tipload (figure 14).

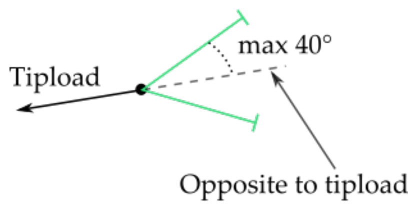

Figure 14: Maximum angle

6 Pole and stay sharing the load

When a pole is stayed, how is the load shared between the pole and the stay?

Figure 15 shows a pole that is fixed at ground level (such as a pole with a concrete foundation). The tipload H is shared between the pole and stay ie $H = H_P + H_S$. The relative magnitudes of the forces H_P and H_S depends on the horizontal stiffnesses K_P and K_s of the pole and stay.

$H_P = H \, x \dfrac{K_P}{(K_P + K_S)}$ and there is a similar equation for H_S . The ratios $K_P/(K_P + K_S)$ and $K_S/(K_P + K_S)$ are distribution factors showing how the load is distributed between the pole and stay.

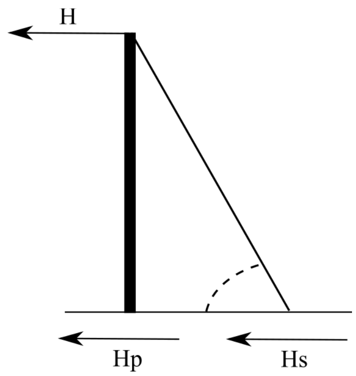

Figure 15: Pole, Stay

For a class S2 pole, 10m out of the ground, 350mm ground line diameter, 250mm tip diameter, K_P is 21.8kN/m. A 7/2.75S steel stay wire, attached at the tip of the pole with an angle of 45° to the ground has a value of 283kN/m for K_S.

The preceding equations show the stay carries 93 % of the tipload.

$$\frac{293}{(21.8+283)}=0.93$$

The remaining 7% of the load is carried by the pole. After foundation movement and pole flexing, the stay carries almost all the load.

If the pole is modelled as being hinged at ground level (the common assumption for timber poles) the pole acts as a strut and takes none of the load – the tipload is transferred in full to the stay.

Accordingly, Poles 'n' Wires assumes the pole acts as a strut in the direction of the tipload, the full tipload is taken by the stay/s and the pole supports only the component of the load perpendicular to the stay for the case of one stay, or no load for correctly placed multiple stays.

Revision history

Rev No.	Date	Details	Rev No.	Date	Details
A	07/03/18	Initial release	D	28/03/19	Clarifications section 5
B	16/05/18	Details on component stiffness, shared load	E	18/03/20	Minor editing
C	06/03/19	Details on assessment of two stays			