Cable Pulling Calculations Tutorial

Cable Pro Web Software

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Introduction

Prior to the installation of cables, it is of upmost importance to perform tension and sidewall pressures calculations. The tensions and sidewall pressures should not exceed the manufacturer's specified limits to avoid damage to the cables.

The tensions and sidewall pressures are affected by the following main factors:

- Sizes of cables and the quantity.
- Route length and bends.
- Method of pulling and formation.
- Friction between cables and surfaces.

This tutorial explains how to use the Cable Pulling module in Cable Pro Web™ software.

Visit www.elek.com.au for information about the software.

Example – Pulling route

The cable pulling route is shown below:

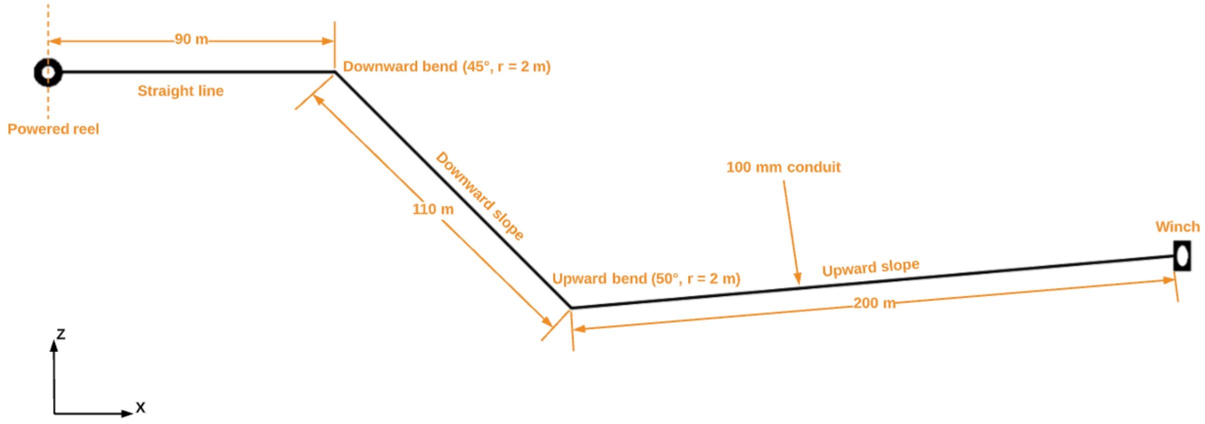

Figure 1 – Pulling (Installation) Route

Three cables will be pulled in trefoil formation inside a 100 mm conduit along the installation route depicted in Figure 1. The route consists of 3 straight sections (1 horizontal, 1 downward slope and 1 upward slope) with 2 bends. There is a powered reel at one end (so reel back tension is 0 N) and a winch at the other.

For this installation the following calculations and checks are needed:

1. Tension and sidewall pressure limits are not exceeded.
2. Cable clearances and jamming probability in the conduit.
3. The above for both forward and reverse pull directions.

Next, we will explore the main user interface and collect the input data of the software.

Software inputs - Overview

There are five main sections to the software's user interface requiring data from the user:

① **Sections** – A cable route is divided into sections, and each is added to the table.

② **Cables** – Enter the quantity of cables and their physical properties. Refer to the cable manufacturers documentation. Multiple cable types are possible.

③ **Formation** – Match the arrangement in which the cable(s) are pulled.

④ **Installation** – Specify the conduit/duct dimensions, direction of pull, reel back tension and reduction factor.

⑤ **Friction** – Enter the values for friction along the route including for the bends which result in high sidewall pressures.

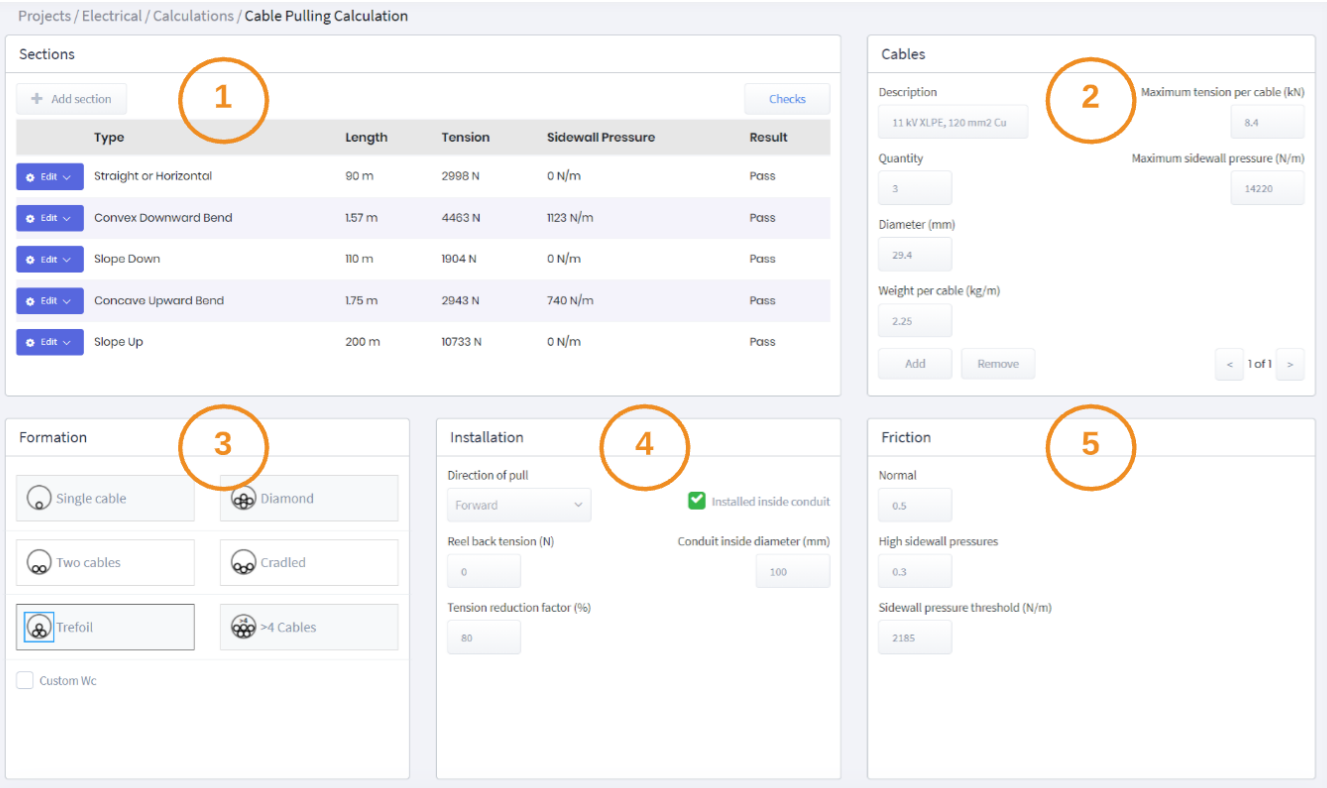

Figure 2 – Cable Pulling Software – Main User Interface

Sections data

The cable pulling route shown in Figure 2 has been divided into sections.

The data to enter for the sections is shown below in Table 1.

Table 1 – Sections data

No.	Type	Input values
1	Reel Back Tension	0 N
2	Straight	Length = 90 m
3	Convex Downward Bend	Angle = 45°, Bend radius = 2 m
4	Slope Down	Length = 110 m, Angle = 45°
5	Concave Upward Bend	Angle = 50°, Bend radius = 2 m
6	Slope Up	Length = 200 m, Angle = 5°

Click on the “**Add Section**” button to include and configure each section of the cable route.

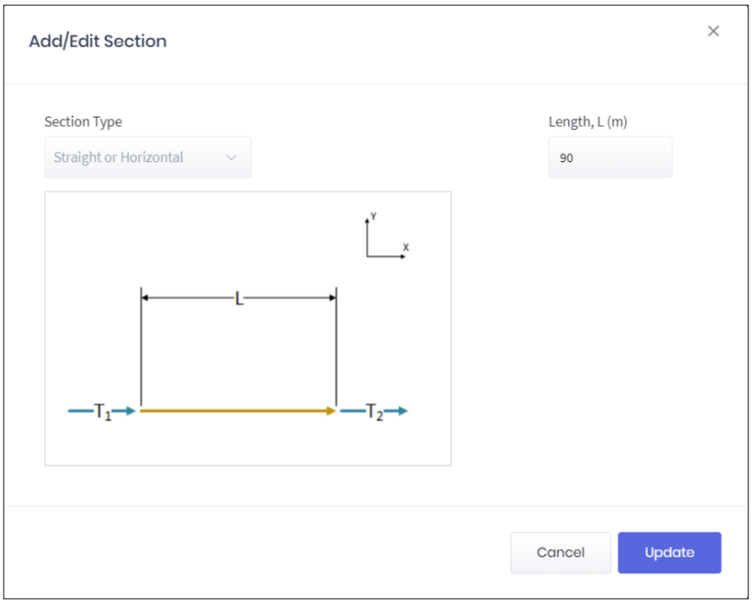

Figure 3 – Add/Edit Section window – Straight section input

Cables data

The cables are 11 kV single core with 120 mm^2 copper conductors which will be pulled in trefoil formation inside the duct. The cable's diagram is given below:

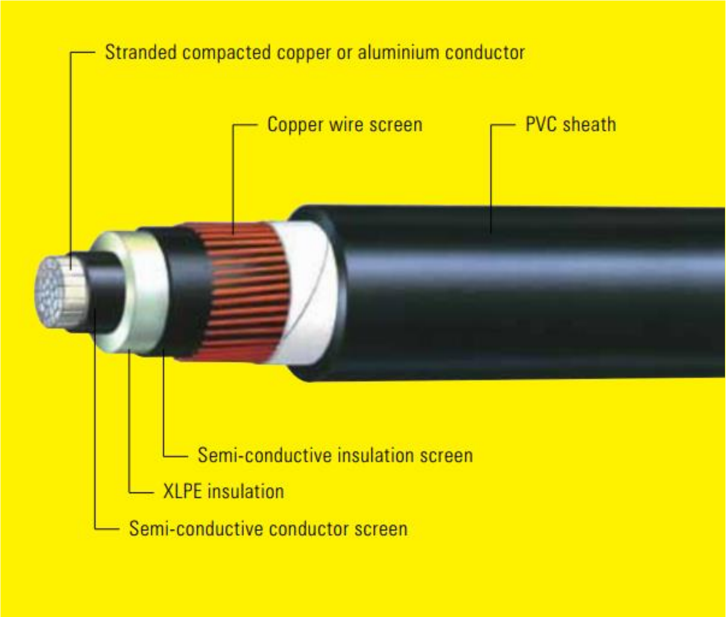

Figure 4 – Cable's diagram

The relevant data has been taken from the cable manufacturer's catalogue.

Table 2 – Cable's data

Parameter	**Value**	**Source**
Cable diameter	29.4 mm	Manufacturer's catalogue (see next page)
Weight per cable	2.25 kg/m	
Maximum tension per cable	8.4 kN	
Maximum sidewall pressure	1450 kg/m → 14220 N/m	

Copper Conductors, up to 10kA Fault Level

Nominal conductor area	Nominal conductor diameter	Nominal insulation thickness	Nominal diameter over insulation	Nominal screen area on each core	Number and nominal diameter of screen wires	Nominal diameter over wire screen	Nominal overall diameter	Approx. mass	Product code	Max. pulling tension	Min. bending radius		Nominal duct diameter	
											During pulling	Set in position	(trefoil)	(circle)
mm^2	mm	mm	mm	mm^2	no/mm	mm	mm	kg/100m		kN	mm	mm	mm	mm
16	4.8	3.4	12.8	15.9	28/0.85	16.1	20.2	59	XJHP15AA001	1.1	360	240	50	65
25	5.8	3.4	13.8	24.4	43/0.85	17.1	21.2	78	XJHP17AA001	1.8	380	250	50	65
35	6.8	3.4	14.8	34.4	24/1.35	19.1	23.2	99	XJHP18AA001	2.5	420	280	50	65
50	8.0	3.4	16.0	48.7	34/1.35	20.3	24.4	125	XJHP19AA001	3.5	440	290	50	80
70	9.6	3.4	17.6	68.1	30/1.70	22.6	26.9	165	XJHP20AA001	4.9	480	320	50	80
95	11.5	3.4	19.4	68.7	48/1.35	23.7	27.9	195	XJHP22AA001	6.7	500	330	50	80
120	13.1	3.4	21.0	68.7	48/1.35	25.3	29.4	225	XJHP23AA001	8.4	530	350	50	100
150	14.5	3.4	22.4	68.7	48/1.35	26.7	31.1	255	XJHP24AA001	11	560	370	63	100
185	16.1	3.4	24.1	68.7	48/1.35	28.4	32.7	285	XJHP25AA001	13	590	390	63	100
240	18.5	3.4	26.5	68.7	48/1.35	30.8	35.3	345	XJHP26AA001	17	640	420	63	100
300	20.7	3.4	28.9	68.7	48/1.35	33.2	37.9	410	XJHP27AA001	21	680	450	63	150
400	23.6	3.4	31.8	68.7	48/1.35	36.3	41.2	505	XJHP28AA001	28	740	490	65	150
500	26.5	3.4	34.7	68.7	48/1.35	39.2	44.3	605	XJHP30AA001	35	800	530	65	150
630	29.9	3.4	38.4	68.7	48/1.35	42.9	48.7	730	XJHP32AA001	44	880	580	80	150
800	35.9	3.4	44.5	68.7	48/1.35	49.0	55.0	925	XJHP33AA001	56	990	660	80	200

3 Overriding Maximum

At no time should the pulling tension exceed 25kN. Olex is to be consulted when the installation tension is expected to exceed 25kN.

4 Sidewall Bearing Pressure

Sidewall bearing pressure (SWBP) is defined as the ratio of cable tension at the exit of a bend to the radius of the bend and can limit the maximum tension that a cable can withstand. The maximum recommended SWBP for Olex HV XLPE cables is 1450kg/m.

Figure 5 – Cable data extracted from manufacturer catalogue

The overall maximum permissible pulling tension on the cables is given as follows:

$$T_{max} = Rf * N * T_{allowable}$$

Where Rf is the Tension Reduction Factor in percentage, N are the number of cables (3) and $T_{allowable}$ is the maximum allowed tension per cable (8,400 N). Tension reduction factor is applied for multiple cables when considering that the forces are not evenly distributed and in this example is assumed to be 80 %.

The overall maximum permissible pulling tension becomes 3 x 8,400 x 80% = **20,160 N**

Formation and Installation data

The formation input affects the weight correction factor which is used internally by the software for calculations so what is selected must match the way the cables will be pulled. In this example, the three cables will be bunched as a **Trefoil bundle** and hauled at once.

The three cables will be hauled inside a **conduit** of **100 mm diameter**.

Friction data

The coefficient of friction has a large impact on the pulling tension calculations. Note that static (stationary) friction is higher than dynamic friction therefore it is not recommended to stop during a cable haul.

Typically, the coefficient of friction will vary between 0.1 and 1 where lubrication is used and can exceed 1 for un-lubricated pulls. The coefficient of friction measured in bends with high sidewall pressures is approximately half the value of straight runs.

The friction data has been taken from the Standard "IEEE Guide for the Design and Installation of Cable Systems in Substations" (IEEE 525-2016).

Table 3 – Friction data

Parameter	**Value**	**Source**
Dry cable or conduit	0.5	IEEE Std. 525-2016
Well-lubricated cable and conduit	0.15 - 0.35	

For this example, the **Normal** coefficient of friction is taken as **0.5**.

It has already been explained the coefficient of friction reduces typically by half from normal during a bend where the sidewall pressure exceeds a pre-defined limit. This fact is being included in this example therefore friction for **High sidewall pressures** is **0.3**.

Results

The calculated tension and sidewall pressures are displayed in the Sections table and the Results are checked automatically.

Sections

Add section | Checks

	Type	Length	Tension	Sidewall Pressure	Result
Edit	Straight or Horizontal	90 m	2998 N	0 N/m	Pass
Edit	Convex Downward Bend	1.57 m	4463 N	1123 N/m	Pass
Edit	Slope Down	110 m	1904 N	0 N/m	Pass
Edit	Concave Upward Bend	1.75 m	2943 N	740 N/m	Pass
Edit	Slope Up	200 m	10733 N	0 N/m	Pass

Figure 6 – Tension and Sidewall Pressure results – Forward direction pull

Sections

Add section | Warnings

	Type	Length	Tension	Sidewall Pressure	Result
Edit	Slope Down	200 m	5482 N	0 N/m	Pass
Edit	Concave Upward Bend	1.75 m	8376 N	2106 N/m	Pass
Edit	Slope Up	110 m	16117 N	0 N/m	Pass
Edit	Convex Downward Bend	1.57 m	20505 N	5157 N/m	Fail
Edit	Straight or Horizontal	90 m	23502 N	0 N/m	Fail

Figure 7 – Tension and Sidewall Pressure results – Reverse direction pull

The maximum tension for a forward direction pull is **10,733 N** and maximum sidewall pressure is **1123 N/m,** while for Reverse Pull Analysis, maximum tension is **23,502 N** and maximum sidewall pressure is **5157 N/m.** Note that the Slope Down section in the forward direction significantly reduces the tension due to the gravity effect.

There are no warnings shown for forward pull direction, however, for the reverse pull direction, the maximum tension has exceeded the specified limit and is shown as a warning. By pressing the **Checks** button, the Calculation Checks window is displayed.

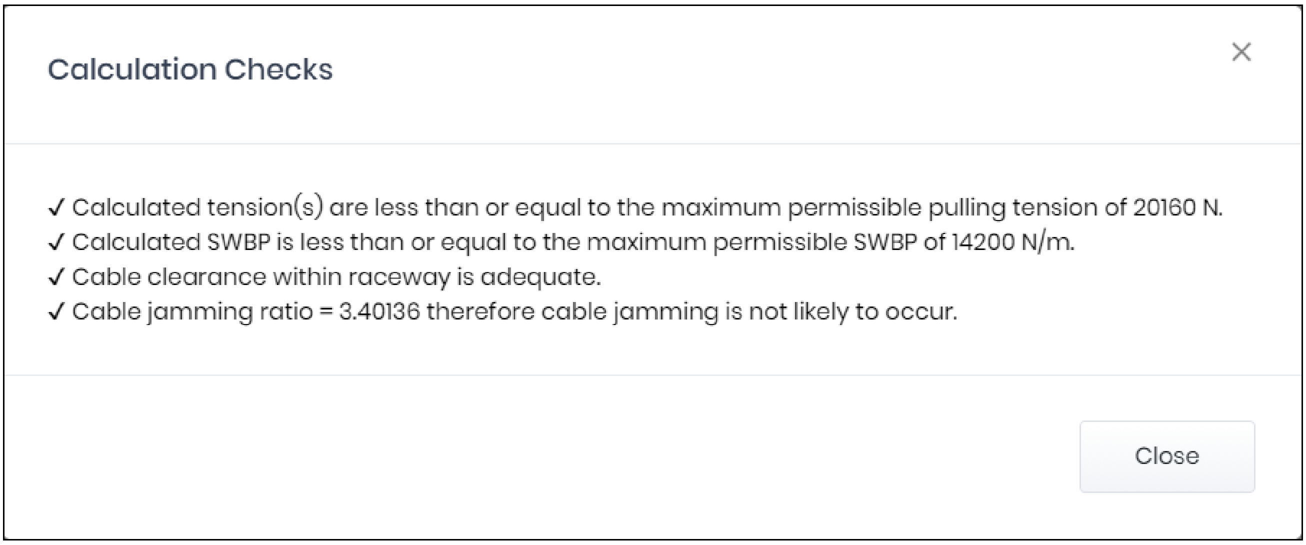

Figure 8 – Calculation Checks window – Forward direction pull

In summary, the maximum tensions and sidewall pressures on the cables are lower than the maximum limits for forward pull direction. The cables clearance inside the conduit is deemed to be adequate and cable jamming probability calculated as not likely to occur. Therefore, the design is acceptable for the forward pull direction, and there should not be damage caused to the cables during installation.